A

SYSTEM

OF

CHEMISTRY,

IN FOUR VOLUMES.

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The Sixth Edition.

VOL. II.

LONDON:
PRINTED FOR BALDWIN, CRADOCK, AND JOY;
FOR W. BLACKWOOD, AND BELL AND BRADFUTE, EDINBURGH;
AND HODGES AND MACARTHUR, DUBLIN.

1820.

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OF

VOLUME SECOND.

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SYSTEM

OF

CHEMISTRY.

BOOK II.

OF COMPOUND BODIES.

Book II. IN the present state of the science of chemistry, I have thought it better to describe several of the compound substances while treating in the last book of the simple bodies, by the union of which they are constituted, than to place all the compounds under distinct heads. A contrary plan has been followed by some modern writers, but I think the result has been such as ought to deter others from imitating their example. The unity of the subject has been destroyed, and the facts have been exhibited in so unconnected a manner, as must considerably retard the progress of the student, while it fatigues and disgusts those who are already acquainted with the subject.

Divisions. Compound bodies are of two kinds. Some of them are formed by the combination of two or more *simple* substances with each other. Thus phosphoric acid is composed of phosphorus and oxygen; and oil, of hydrogen and carbon. Others are formed by the combination of two or more *compound* bodies with each other. Thus phosphate of ammonia is composed of phosphoric acid and ammonia; volatile liniment, of oil and ammonia. The first of these kinds of compounds I call *Primary Compounds;* to the second I give the name of *Secondary Compounds.* It will be convenient to describe each of them separately. I shall therefore subdivide this book into two divisions. In the first I shall treat of *primary compounds*, and in the second of *secondary compounds.*

DIVISION I.

OF PRIMARY COMPOUNDS.

I have already given an account of the different compounds which the simple combustibles* form with each other. We have here therefore only to examine the different primary compounds formed by the union of the *combustibles* with the *supporters of combustion.* Besides the four simple supporters, there is another substance, *cyanogen*, which forms compounds analogous to those formed by the supporters. It will be advantageous therefore to consider it as a supporter, and to place the compounds which it forms among the primary compounds. Besides the combinations of supporters with combustibles, there are some substances formed by the union of certain combustibles with each other, or with oxygen, of so much importance in chemistry, that they require a particular description; yet so imperfectly analysed that we cannot venture to class them according to their composition. These I shall place among the primary compounds under the title of *compound combustibles.* Primary compounds then will be described under the six following heads.

Classes of primary compounds.

I. Compounds of oxygen with simple combustibles.

II. Compounds of chlorine with supporters and combustibles.

III. Compounds of iodine, with supporters and combustibles.

IV. Compounds of fluorine, with supporters and combustibles.

V. Compounds of cyanogen, with supporters and combustibles.

VI. Compound combustibles.

We shall take these different heads in the order in which they have been enumerated.

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* To avoid too many subdivisions I include *azote* among the combustibles, though, strictly speaking, it ought to constitute a class by itself.

SUBDIVISION I.

OF COMPOUNDS OF OXYGEN WITH SIMPLE COMBUSTIBLES.

Subdivis. I. Chap. I.

The compounds which oxygen forms with the simple combustibles are of three different kinds. Some possess the properties of *acids*. Some are capable of neutralizing acids and forming salts; on which account they have received the name of *salifiable bases*. Some are neither acids nor capable of neutralizing acids. They have hitherto been called simply *oxides;* but we shall distinguish them by the name of *unsalifiable* oxides. We shall consider these three sets of compounds separately. This division therefore will consist of *three* chapters. In the *first* I shall describe the *unsalifiable oxides;* in the *second* the *salifiable bases;* and in the *third* the *acids*.

CHAP. I.

OF UNSALIFIABLE OXIDES.

The only simple combustibles, as far as we know at present, capable of uniting with oxygen, and forming unsalifiable oxides, are azote, hydrogen, and carbon. Azote forms two such oxides, namely, the *protoxide* and the *deutoxide of azote*, hydrogen gas forms two, namely *water* and *peroxide of hydrogen;* and carbon forms one, namely, *carbonic oxide*. These five oxides will be described in the following sections.

SECT. I.

OF PROTOXIDE OF AZOTE.

History.

Protoxide of azote was discovered by Dr. Priestley about the year 1776, and called by him *dephlogisticated nitrous gas*. He procured it first by keeping iron filings in nitrous gas, and by keeping a mixture of iron and sulphur in the same gas.* The associated Dutch chemists examined it in 1793, and demonstrated it to be a compound of azote and oxygen.† But for a full investigation of its properties we are indebted to

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* Priestley on Air, ii. 54.

† Jour. de Phys. xlii 323.

Sir H. Davy, who published an excellent dissertation on it in the year 1800. He gave it the name of *nitrous oxide.*[*]

Preparation.

1. It may be procured by the following process: take any quantity of *nitrate of ammonia* (a salt composed of nitric acid and ammonia) in crystals, and expose it in a retort, by means of a lamp, to a heat not under 340°, nor above 500°. It melts rapidly, and is decomposed, emitting a great quantity of gas, which issues from the mouth of the retort, and may be received in glass jars in the usual manner. The gas which comes over is *protoxide of azote.* This process was first pointed out by Berthollet; but it was much simplified by Davy.[†]

Properties.

2. Protoxide of azote, thus obtained, has all the mechanical properties of air: but it is much heavier than air; its specific gravity being 1·5277.

It is capable of supporting combustion even better than common air; almost as well indeed as oxygen gas. A candle burns in it with a brilliant flame and a crackling noise. No combustible, however, burns in it, unless it be previously brought to a state of ignition.

Dr. Priestley and the Dutch chemists had concluded that it cannot be respired; but they did not examine it in a state of purity.[‡] Davy ascertained that it may be breathed for several minutes without any bad effects. The feelings produced by breathing it bear a strong resemblance to intoxication; but they are not followed by that langour and debility which is a constant attendant of intoxication. It cannot be breathed longer than about four minutes, without the loss of voluntary motion altogether. When animals are confined in it, they give no signs of uneasiness for some moments; but they soon become restless, and, if not removed in a very few minutes, die altogether. Hence we see that, though this gas be respirable, it is much less so than common air or oxygen gas.[§]

Action of water.

3. This gaseous oxide is absorbed pretty rapidly by water, as Dr. Priestley ascertained, especially when agitated. According to the experiments of Saussure, 100 measures of water

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[*] Researches, chiefly concerning Nitrous Oxide.

[†] Mr. Proust has remarked that, the gas which comes over at the beginning of the process differs a little from nitrous oxide, and yet it is not *nitrous gas.* This happens only when the salt contains muriate of ammonia.

[‡] Dr. Priestley indeed found, in one instance, that a mouse breathed it five minutes without uneasiness. In this experiment he seems to have obtained it nearly pure.—Priestley, ii. 84.

[§] Davy's Researches, p. 94.

absorb 76 measures of this gas, and 100 measures of alcohol of the specific gravity 0·84 absorb 153 measures.[*] The water acquires a sweetish taste; but its other properties do not differ perceptibly from common water. The whole of the gas is expelled unaltered by boiling the water.[†] When this gas combines with the water, it expels the common air which was formerly dissolved in the water. Hence the residuum of common air, which always appears when this gaseous oxide is exposed to a sufficient quantity of water.[‡]

4. This gas is not altered by exposure to light, nor to any heat below ignition; but when made to pass through a red-hot porcelain tube, or when electric sparks are made to traverse this gas, it is decomposed, and converted into *nitric acid* and *common air*.[§]

Of supporters.

II. None of the simple supporters, as far as is known, produce any change upon this gas, even when heated in contact with it.

Of simple combustibles.

III. As it is a supporter of combustion it is obvious that the simple combustibles (some of them at least) must decompose it in certain circumstances.

1. Hydrogen gas and protoxide of azote detonate violently with a red flame, when a strong red heat is applied, or when the electric spark is made to pass through the mixture. When the proportion of hydrogen is equal to that of the oxide, the products are water and azote; when the proportion of hydrogen is small, nitric acid is also formed.[||]

2. Charcoal, confined in this gaseous oxide, may be kindled by means of a burning-glass. It continues to burn with great brilliancy, till about the half of the gas is consumed. The products are carbonic acid gas and azotic gas.[**]

3. We do not know the action of boron and silicon on this gas from experiment. But there can be no doubt that they would burn in it and deprive it of the whole of its oxygen.

Phosphorus.

4. Phosphorus may be melted and sublimed in this gas without alteration; it may be even touched with a red-hot wire without undergoing combustion; but when touched with a wire heated to whiteness, it burns, or rather detonates with prodigious violence. The products are, azotic gas, phospho-

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[*] Annals of Philosophy, vi. 340.

[†] Priestley, ii. 81.

[‡] Davy's Researches, p. 89.

[§] Priestley, ii. 91, and Davy, ibid. p. 279.

[||] Priestley, ii. 83, and Davy, p. 286.

[**] Davy, p. 311.

ric acid, and nitric acid: a part of the oxide remains undecomposed.*

Sulphur.

5. Sulphur, at the common temperature of the air, is not altered by this gas. If it be introduced into it while burning with a blue flame, it is immediately extinguished; but if introduced while burning with a white flame, it continues to burn for some time with great brilliancy, and with a fine red flame. The products are sulphuric acid and azote. When about the half of the protoxide is decomposed, the sulphur is extinguished.†

Sulphuretted, phosphuretted, and carburetted hydrogen gas, likewise burn when mixed with protoxide of azote, and exposed to a strong red heat. The products differ according to the proportions of the gases mixed.

6. No experiments have been made to ascertain the action of arsenic and tellurium on this gas. The probability is that they would both deprive it of its oxygen, and that they might be made to burn in it.

7. The action of the alkalifiable combustibles on this gas has been but very imperfectly examined.

(1.) When potassium is heated in it the metal takes fire, and is first converted into peroxide of potassium. If the heat be continued the peroxide is decomposed in its turn, and is reduced to the state of nitrite of potash. The protoxide of azote is converted into a mixture of nitrous gas and azote.‡ Sodium produces exactly the same effects on this gas.§

(2.) There can be no doubt that the metallic bases of the alkaline earths and earths proper would decompose this gas if they were heated in it; though hitherto the experiment has not been tried.

Of the metals.

(3.) Iron wire burns in this gas with the same brilliancy as in oxygen gas, though the combustion lasts but a very short time. The iron is converted into black oxide; part of the nitrous oxide is decomposed, its azote is evolved, while its oxygen combines with the iron.‖ Zinc also may be oxidized in this gas.** Its effect upon the other metals has not been tried.

IV. Sir Humphry Davy was of opinion that protoxide of azote has the property of combining with alkalies, and of form-

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* Davy's Researches, p. 303.

† Davy, ibid.

‡ Gay-Lussac and Thenard. Recherches Physico-chimiques, i. 263.

§ Ibid. p. 167.

‖ Priestley, ii. 13, and Davy, p. 286.

** Davy, p. 371.

ing a peculiar kind of salt, to which he gave the name of *nitroxi*, and which I afterwards called *azotite*. He formed these compounds by bringing the alkali in contact with the protoxide of azote at the instant of its formation. Thus he exposed a mixture of sulphite of potash and potash to nitrous gas. The sulphite deprived the nitrous gas of a portion of its oxygen, and converted it into protoxide of azote, and this protoxide united with the potash and formed the compound in question; which was afterwards separated from the sulphate of potash by solution and crystallization.*

I have little doubt from the description of the salts formed by Davy, that they were in reality *nitrites* of potash and soda. They were obviously the same with the salts formed by Gay-Lussac and Thenard, by heating potassium and sodium in protoxide of azote.†

Composition.

V. From the experiments of Davy‡ compared with those of Gay-Lussac and Thenard,§ there can be no doubt that protoxide of azote is a compound of 1 volume azotic gas and $\frac{1}{2}$ volume of oxygen gas condensed into 1 volume. Or of 1 atom azote + 1 atom oxygen, or by weight of

Azote	1·75	100
Oxygen	1·00	57·14

Hence, if to 0·9722, the specific gravity of azotic gas, we add 0·5555, half the specific gravity of oxygen gas, we obtain 1·5277, which is the specific gravity of gaseous protoxide of azote.

SECT. II.

OF DEUTOXIDE OF AZOTE.

History.

Deutoxide of azote, usually denominated *nitrous gas*, was obtained accidentally by Dr. Hales; but its nature and properties were investigated by Priestley, in one of the first excursions made by that illustrious philosopher into the then unbeaten tracts of pneumatic chemistry. As the phenomena exhibited by this oxide are intimately connected with the most important investigations in chemistry, its properties were exa-

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* Davy's Researches, p. 268.

† From an experiment of Gay-Lussac, it is obvious that the sulphite of potash used by Davy was superfluous. See Ann. de Chim. et Phys. i. 397.

‡ Researches, p. 278.

§ Recherches Physico-chimiques, i. 166.

mined with great care, and occupied the attention of almost every chemist of eminence.

Preparation.

1. It may be obtained by the following process: Put copper or mercury into a glass retort, and pour over it somewhat diluted nitric acid. The metal is rapidly dissolved with a strong effervescence, and a great quantity of gas issues from the mouth of the retort, which may be received in glass jars. This gas is *nitrous gas.*

Properties.

2. When pure it is invisible like common air, of which it possesses the mechanical properties. Its specific gravity is 1·0416.

Nitrous gas is exceedingly noxious to animals, producing instant suffocation whenever they attempt to breathe it.

Supports combustion.

The greater number of combustible bodies refuse to burn in it: A taper, for instance, is extinguished the moment it is plunged into nitrous gas; the same thing happens to sulphur, even though previously burning with a white flame. It is capable, however, of supporting the combustion of several bodies, as has been ascertained by the experiments of Priestley and Davy. When Homberg's pyrophorus is introduced into nitrous gas, it takes fire spontaneously, just as it does in common air. Phosphorus, too, when introduced into this gas in a state of inflammation, burns with as much splendour as in oxygen gas.*

Action of air,

4. When nitrous gas and common air are mixed together, the mixture instantly assumes a yellow colour, heat is evolved, and the bulk of the two gases diminishes considerably; slowly, if the experiment be made over mercury; but rapidly, if it be made over water. When the diminution has reached its maximum, the mixture becomes perfectly transparent. The yellow colour is owing to a quantity of nitrous acid which is formed, and the diminution of bulk to the gradual absorption and condensation of this acid. What remains after this absorption is only azotic gas. The cause of this remarkable phenomenon is obvious. The nitrous gas combines with the oxygen of the air, and forms nitrous acid, which is condensed while the azote of the air remains behind in the form of a gas. Hence with equal quantities of nitrous gas and air the diminution of bulk is always proportional to the quantity of oxygen present in the air. Hence it informs us of the proportion of that substance in any particular air. The same phenomenon

And oxygen,

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* Davy, p. 134.

takes place when oxygen gas and nitrous gas are mixed; but the condensation is much more considerable. Indeed it would be complete, provided the two gases were perfectly pure, and mixed in the proper proportions.

Compounds with oxygen.

Many experiments have been made in order to determine the proportions in which nitrous gas and oxygen gas unite together. But the subject is of very difficult determination. Dalton first gave a satisfactory explanation of the anomalies, by showing that oxygen is capable of uniting with two different proportions of nitrous gas. 21 measures of oxygen gas unite, according to him, with 36 measures or with 36 × 2 = 72 measures of nitrous gas.[*] In his *New System of Chemical Philosophy*, he gives the result of his experiments at considerable length, and states the quantity of nitrous gas capable of uniting with 100 volumes of oxygen at 130, 180, 360 volumes.[†] Sir H. Davy relates the result of a great many experiments on these combinations; but he was not able to arrive at very definite conclusions.[‡] Gay-Lussac has renewed his experiments on this subject at different times. The conclusions which he has drawn are that 100 volumes of oxygen gas is capable of combining with

133 volumes
200
400

of nitrous gas.[§] These numbers are probably near the truth. I think it but fair, however, to state that I have never been able to verify the combination of 100 oxygen with 400 nitrous gas. But as all the intermediate proportions between these extremes are capable also of uniting with 100 volumes of oxygen, it is very difficult to obtain definite results. The compounds formed are

Nitric acid with 100 volumes oxygen + 133 nitrous gas
Nitrous acid .... 100 .... + 200
Hyponitrous acid 100 .... + 400

5. When electric sparks are made to pass through nitrous gas, it is decomposed and converted into nitrous acid and

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[*] Phil. Mag. xxiii. 351.

[†] Vol. ii. p. 327.

[‡] Elements of Chemical Philosophy, p. 260. He makes, however, the important deduction that nitric acid is a compound of 100 oxygen + 133 nitrous gas.

[§] Ann. de Chim. et Phys. i. 394.

azotic gas.* Gay-Lussac has shown that when strongly heated it undergoes the same decompositions.†

Absorbed by water.

6. Nitrous gas is readily absorbed by water. From an experiment of Davy, it appears that 100 cubic inches of water at the common temperature, and previously freed from air, absorb 11·8 cubic inches of nitrous gas, or nearly one-tenth, as Dr. Priestley had ascertained; but the experiments of Dr. Henry do not accord with this estimate. Water, by his trials, at the temperature of 60°, absorbs only five per cent. of its bulk of this gas.‡ This solution has no particular taste, and does not redden blue vegetable colours. The gas is expelled again by boiling the water; § it separates likewise when the water is frozen.||

II. The simple supporters (oxygen excepted) have no action on nitrous gas while dry. But chlorine, when assisted by water, converts it into nitrous acid.

Action of combustibles,

III. The action of the simple combustibles on nitrous gas has not been examined with the minuteness that it deserves.

1. Hydrogen gas mixed with it acquires the property of burning with a green flame. A mixture of these two gases does not take fire when electric sparks are made to pass through it; but according to Fourcroy, it detonates when made to pass through a red hot porcelain tube; water is formed, and azotic gas is evolved.**

2. Nitrous gas is decomposed by phosphorus and charcoal at a very high temperature, and probably also by sulphur. These substances are converted into acids by combining with the oxygen of the gas while its azote is evolved.

And metals.

3. Several of the metals have the property of decomposing it, especially when assisted by heat. This is the case particularly with iron. Dr. Priestley confined a portion of nitrous gas for some time in contact with a number of iron nails; the gas was converted into oxide of azote, in consequence, doubtless, of the iron abstracting part of its oxygen.†† It was in this manner that protoxide of azote was discovered by that philosopher. When the iron is heated to redness by means of a burning-glass, the decomposition is complete, the whole of the oxygen is abstracted from the nitrous gas, and only azotic

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* Priestley, ii. 22.

† Ann. de Chim. et Phys. i. 398.

‡ Phil. Trans. 1803, p. 274.

§ Davy, p. 143.

|| Priestley, ii. 407.

** Fourcroy, ii. 91.

†† Priestley, ii. 54.

gas remains behind.* Potassium acts upon this gas precisely as on protoxide of azote, and is converted first into peroxide of potassium, and then into nitrite of potash. But sodium does not undergo the same changes in it.†

Absorbed by sulphate of iron.

IV. Dr. Priestley ascertained that nitrous gas is absorbed by the green sulphate of iron; a property which is employed successfully to ascertain its purity. All that is necessary is, to expose a given portion of nitrous gas in a close vessel to the action of the green sulphate; the quantity of gas which remains unabsorbed gives the proportion of foreign bodies with which it is mixed. Davy has proved, that all the salts containing the black oxide of iron possess the same property, and that they all absorb nitrous gas unaltered. The greatest part of it may be even expelled again by the application of heat. Several other metallic salts possess the same properties.‡

Converted into nitrous oxide.

The following bodies have the property of converting deutoxide of azote into protoxide:

Alkaline sulphites,
Hydroguretted sulphurets,
Muriate of tin,
Sulphuretted hydrogen gas,
Iron or zinc filings moistened with water.

To produce this effect, nothing more is necessary than to put these substances into jars filled with deutoxide of azote, and allow them to remain for a week or two. The substances gradually combine with a portion of oxygen, and are converted into oxides or salts.§

V. From the experiments of Davy compared with those of Gay-Lussac and Thenard, there can be no doubt that nitrous gas is a compound of 1 volume of azotic gas + 1 volume of oxygen gas, constituting together 2 volumes. Hence it is a compound of 1 atom azote + 2 atoms oxygen; or by weight of

Azote	1·75	100
Oxygen	2	114·28

And its specific gravity is the mean between 1·1111, the specific gravity of oxygen gas, and 0·9722, the specific gravity of azotic gas. For that mean is obviously 1·04165.

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* Fourcroy, ii. p. 38.

† Recherches Physico-chimiques, i. 161.

‡ Davy, p. 179.

§ Priestley and Davy, *passim.*—During the action of the two last bodies on nitrous gas, ammonia is likewise formed.

SECT. III.

OF WATER.

Book II. Division I.

THIS well known liquid is found in abundance in every part of the world, and is absolutely necessary for the existence of animals and vegetables. When pure, in which state it can be obtained only by distillation, it is transparent, and destitute of colour, taste, and smell.

Weight.

1. As this liquid, from the ease with which it may be procured in a state of purity, has been chosen for a standard by which the comparative weight of all other bodies may be estimated, it becomes of the greatest importance to ascertain its weight with precision: but its density varies with the temperature.

Mr. Rice, from a careful comparison of the experiments of Lefevre Gineau* and Sir George Shuckburgh,† has shown that when the thermometer stands at 60°, and the barometer at 30 inches, the weight of a cubic inch of distilled water weighs 252·525 grains troy. He has shown likewise that the specific gravity of water is to that of air as 827·437 : 1. Hence the weight of 100 cubic inches of air under the same pressure and at the same temperature is 30·519 grains.‡

The specific gravity of water is always supposed = 1·000, and it is made the measure of the specific gravity of every other body.

Ice.

2. When water is cooled down to 32°, it assumes the form of ice. If this process goes on very slowly, the ice assumes the form of crystalline needles, crossing each other at angles, either of 60° or 120°, as Mr. de Mairan has remarked; and it has been often observed in large crystals of determinate figures.§ Ice, while kept at a temperature considerably below 32°, is very hard, and may be pounded into the finest dust. It is elastic. Its specific gravity is less than that of water, being only 0·94.

Steam.

3. When water is heated to the temperature of 212°, it boils, and is gradually converted into steam. Steam is an invisible fluid like air, but of a less specific gravity. According

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* Jour. de Phys. xlix. 171. † Phil. Trans. 1777, and 1798.

‡ Annals of Philosophy, xiii. 339, and xiv. 73.

§ See observations on this subject by Grew. Phil. Trans. Abr. ii. 51.

to the experiments of Gay-Lussac its bulk, under a pressure of 29·922 inches of mercury and at the temperature of boiling water, is 1698 times greater than when in the liquid state. Hence its specific gravity is 0·6235, that of air being reckoned 1.* If we suppose its density to that of air as 10 : 16, its specific gravity will be 0·625. If we suppose it composed of 2 volumes hydrogen and 1 volume oxygen condensed into 2 volumes, its specific gravity will be 0·62495.

The elasticity of steam is so great, that it produces the most violent explosions when confined. It is upon this principle that the steam-engine has been constructed.

Boiling point affected by salts.

The phenomena of boiling are owing entirely to the rapid formation of steam at the bottom of the vessel. The boiling point of water varies according to the pressure of the atmosphere. In a vacuum water boils at 70°; and when water is confined in a Papin's digester, it may be almost heated red hot without boiling. The mixture of various salts with water affect its boiling point considerably. Mr. Achard made a number of experiments on that subject; the result of which may be seen in the following TABLES.†

CLASS I. *Salts which do not affect the Boiling Point.*

Sulphate of copper.

CLASS II. *Salts which raise the Boiling Point.*

A saturated solution of	Raises the boiling point
Muriate of soda	10·35°
Sulphate of soda	5·6
Sulphate of potash	0·9
Nitrate of potash	3·5
Boracic acid	2·2
Carbonate of soda	2·35

This augmentation varies with the quantity of salt dissolved. In general, it is the greater the nearer the solution approaches to saturation.

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* Gilbert's Annalen, 45, 333.

† Trans. Berlin, 1785. I have not ventured to make any alteration in these tables, as I have not repeated the experiments myself; but I entertain doubts respecting the accuracy of some of the numbers, and believe the third and fourth classes to be wrong.

CLASS III. *Salts which lower the Boiling Point.*

Borax,	In a small quantity, lowers the boiling point	1·350°
	Saturated solution of	0·22
Sulphate of magnesia,	In a small quantity	2·47
	Saturated solution of	1·1
Alum,	A very small quantity of	0·0
	A greater quantity	0·7
	A saturated solution of	0·0
Sulphate of lime,	in any proportion,	0·02
Sulphate of zinc,		0·45
Sulphate of iron,		0·22
Acetate of lead,		1·24

CLASS IV.

Muriate of ammonia,	Small quantity of, lowers the boiling point	0·45°
	Saturated solution of, raises do.	9·79
Carbonate of potash,	Small quantity of, lowers do.	0·45
	Saturated solution of, raises do.	11·2

Water was once supposed to be incompressible; but the contrary has been demonstrated by Mr. Canton. The Abbé Mongez made a number of experiments, long after that philosopher, on the same subject, and obtained similar results.

Action of heat.

4. Water is not altered by being made to pass through a red hot tube. Heat does not seem capable of decomposing it; neither is it affected by the action of light.

Absorbs air.

5. It has the property of absorbing atmospheric air; and it always contains a portion of it when it has been exposed to the atmosphere. The greater part of this air is driven off by boiling: but, from the experiments of Dr. Priestley, it appears that the whole of it is not separated; nor can it be completely separated without great difficulty. Water owes its agreeable taste to the presence of air; hence the insipidity of boiled water. It absorbs oxygen gas in preference to air, and nearly in the same proportion, as was first ascertained by Scheele.

How air may be separated from it.

Mr. Driessen has shown, that in order to free water from air, it must be boiled at least for two hours, and kept in a flask with its mouth inverted over mercury. If it be exposed to the air, after this process, for ever so short a time, it immediately absorbs some air; a proof of the strong affinity which it has for that fluid.* This philosopher has pointed out the following method of ascertaining whether water be perfectly free from air. Tinge the water blue with litmus, fill a flask with it, invert the flask under water, and introduce into it pure nitrous gas till about $\frac{1}{20}$ of the vessel is filled. If the water contains air, a portion of the nitrous gas will combine with its oxygen, and be converted into nitric acid. The consequence of which will be, that the litmus will assume a red colour. Even the proportion of air in the water may be estimated by the quantity of ammonia necessary to restore the blue colour to the litmus. If the litmus retains its blue colour, we may be certain that the water which we try contains no sensible portion of air.† It is proper to remark, however, that this experiment does not succeed in a satisfactory manner, unless an unusual quantity of oxygen gas be present. No effect is produced when nitrous gas is agitated with good spring or river water.

II. None of the supporters of combustion, as far as we know at present, is capable of decomposing water. Hence it appears that hydrogen has a stronger affinity for oxygen than for any of the other supporters of combustion.

Action of combustibles.

III. The action of the simple combustibles on water has not been examined with much care. Hydrogen gas has no action on it even at a red heat. Charcoal does not act sensibly while cold, but at a red heat it decomposes water, carbonic acid and carburetted hydrogen being formed, and probably also carbonic oxide.

2. The action of boron and silicon has not been tried. But it is probable that these bodies would act with, at least, as much energy upon water as charcoal does.

3. Phosphorus and sulphur do not seem capable of decomposing water even when assisted by heat. Arsenic does not decompose it at the common temperature of the atmosphere.

4. Potassium and sodium decompose water with great energy, being converted into potash and soda, while hydrogen gas is evolved. There can be no doubt that the metallic bases of the alkaline earths and earths proper would also decompose water if they were put into that liquid.

Of metals,

5. Iron, zinc, antimony, and tin, decompose it when assisted by heat; silver, gold, copper, and platinum, have no effect upon

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* Phil. Mag. 1803, xv. 252.

† Ibid.

it. The action of the other metals at a red heat has not been tried.*

Alkalies and earths.

6. Water dissolves the alkalies and alkaline earths. The earths proper are insoluble in it. It dissolves also acids and salts, and is capable of combining with a great variety of bodies.

Water combines in two forms.

7. Water has the property of uniting with bodies in two different ways. Some it dissolves; the compound becomes liquid, like water. In this way it unites with common salt, with sugar, and a vast number of other bodies. Other substances combine with it without losing their solidity. The water in this case loses its liquid form, and assumes that of the substance to which it has united. In this way it unites to lime, to alumina, to many saline bodies, and to a variety of metallic oxides. When the compound of water with another substance remains liquid, the proportion of water is unlimited; but when the combination formed is solid, the water combines always in a certain determinate proportion.

To the first of these combinations, or the *solutions* of bodies in water, as they have been termed, considerable attention has always been paid; but the second kind, in which the water assumes a solid form, was very much overlooked, if not altogether neglected, till the attention of chemists was drawn to them by Mr. Proust, who has given to such combinations the name of *hydrates*. Thus the combination of lime and water, usually called *slacked lime*, is in his language a *hydrate* of lime: in like manner, the crystals of barytes and strontian are hydrates of these alkaline earths, and crystallized potash and soda are hydrates of the fixed alkalies. Though the term *hydrate* is in some respects exceptionable, we shall continue to use it, as no other has been suggested. The compounds called *hydrates* deserve attention, since they differ very considerably in their properties from those bodies with which they have been hitherto confounded. Thus the hydrates of lime, barytes, potash, &c. are very different in several respects from lime, barytes, potash, &c.

Hydrates.

Alkaline and earthly hydrates.

The hydrates of potash and soda are crystallized, and contain always a determinate proportion of water. When dissolved in water they occasion cold; whereas the alkalies in the state of powder produce heat. The same observations are applicable to the hydrates of barytes and strontian. The proportion

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* Mem. Par. 1781, p. 273.

of water which combines with lime is much less considerable than that which enters into the composition of the hydrates just mentioned. Hence the hydrate of lime does not crystallize, but remains usually in the state of a powder. We know, however, that it retains the water with great obstinacy, and that the formation of it is one of the principal causes of the solidification of mortar.* The hydrate of alumina is no less remarkable for the obstinacy with which it retains its water. It is the substance to which Saussure gave the name of *spongy alumina.*

Metalline.

But the hydrates of the metallic oxides are the most remarkable. They first drew the attention of Proust, and induced him to invent the term hydrate. His observations, as far as regards the *hydrate of copper*, have been called in question by Berthollet junior;† but his arguments do not appear to me sufficiently conclusive to overturn the ingenious theory of the other chemist. He has demonstrated indeed, that the *hydrate of copper* usually retains a small portion of acid; but he has not shown that its peculiar properties are owing to that acid, while Proust has made the contrary more than probable, by ascertaining that the properties of the hydrate remain the same, even when the proportion of acid varies, and when it is so far diminished as to be no longer perceptible.

Most of the metallic hydrates are remarkable for the brilliancy of their colours. They are much more easily dissolved by acids than the oxides; and when put into the mouth they affect the organs of taste even more powerfully than the metallic salts.

Opinions about the nature of water.

IV. Water was believed by the ancients to be one of the four elements of which every other body is composed; and, according to Hippocrates, it was the substance which nourishes and supports plants and animals. That water was an unchangeable element continued to be believed till the time of Van Helmont, who made plants grow for a long time in pure water: from which experiment it was concluded, that water was convertible into all the substances found in vegetables. Mr. Boyle having digested pure water in a glass vessel hermetically sealed for above a year, obtained a quantity of earthy scales; and concluded, in consequence, that he had converted it partly into earth.‡ He obtained the same earth by distilling water

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* See Proust, Jour. de Phys. lix. 34.

† Statique Chimique, ii. 455.

‡ Shaw's Boyle, iii. 417.

in a tall glass vessel over a slow fire.* Margraff repeated the experiment with the same result, and accordingly drew the same conclusion. But the opinion of these philosophers was never very generally received.† The last person who embraced it was probably Mr. Waselton, who published his experiments on the subject in the Journal de Physique for 1780. Mr. Lavoisier had proved, as early as 1773, that the glass vessels in which the distillation was performed lost a weight exactly equal to the earth obtained.‡ Hence it follows irresistibly that the appearance of the earth, which was silica, proceeded from the decomposition of the vessels; for glass contains a large proportion of silica. It has been since shown by Dr. Priestley, that water always decomposes glass when applied to its surface for a long time in a high temperature.

History of the discovery of its component parts.

Water is now known to be an oxide of hydrogen, or a compound of oxygen and hydrogen. As this discovery has almost entirely altered the appearance of the science of chemistry, by furnishing an explanation of a vast number of phenomena which were formerly inexplicable, it will be worth while to give a particular account of the different steps which gradually led to it.

The first person probably who attempted to discover what was produced by burning hydrogen gas was Scheele. He concluded, that during the combustion oxygen and hydrogen combined, and that the product was caloric.

In 1776 Macquer, assisted by Sigaud de la Fond, set fire to a bottle full of hydrogen gas, and placed a saucer above the flame, in order to see whether any fuliginous smoke would be produced. The saucer remained perfectly clean; but it was moistened with drops of a clear liquid, which they found to be pure water.§

Next year Bucquet and Lavoisier exploded oxygen and hydrogen gas, and made an attempt to discover what was the product; about the nature of which they had formed different conjectures. Bucquet had supposed that it would be carbonic acid gas; Lavoisier, on the contrary, suspected that it would

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* Shaw's Boyle, i. 267.

† See an account of all the facts relating to this subject in Watson's Chemical Essays, iv. 257.

‡ Mem. Paris, 1770, pp. 73, 90. This paper consists of two memoirs. In the first Lavoisier gives a full history of the opinions of preceding writers on this subject; in the second, he gives a detail of his experiments.

§ Macquer's Dictionary, art. Gas inflammable.

be sulphuric or sulphurous acid. What the product was they did not discover; but they proved that no carbonic acid gas was formed, and consequently that Mr. Bucquet's hypothesis was ill-founded.*

In the beginning of the year 1781, Mr. Warltire, at the request of Dr. Priestley, fired a mixture of these two gases contained in a copper vessel; and observed that, after the experiment, the weight of the whole was diminished. Dr. Priestley had previously, in the presence of Mr. Warltire, performed the same experiment in a glass vessel. This vessel became moist in the inside, and was covered with a sooty substance,† which Dr. Priestley afterwards supposed to be a part of the mercury used in filling the vessel.‡

In the summer of 1781, Mr. Cavendish, who had been informed of the experiments of Priestley and Warltire, set fire to 500,000 grain measures of hydrogen gas, mixed with about 2½ times that quantity of common air. By this process he obtained 135 grains of pure water. He also exploded 19,500 grain measures of oxygen gas, with 37,000 of hydrogen gas, and obtained 30 grains of water, containing in it a little nitric acid. From these experiments he concluded that water is a compound.—Mr. Cavendish must therefore be considered as the real discoverer of the composition of water. He was the first who ascertained that water is produced by firing oxygen and hydrogen gas, and the first who drew the proper concluclusion from that fact. Mr. Watt, indeed, had also drawn the proper conclusion from the experiments of Dr. Priestley and Mr. Warltire, and had even performed a number of experiments himself to ascertain the fact before Mr. Cavendish had communicated his; but he had been deterred from publishing his theory by some experiments of Dr. Priestley, which appeared contrary to it.§ He has therefore a claim to the merit of the discovery; a claim however, which does not affect Mr. Cavendish, who knew nothing of the theory and experiments of that ingenious philosopher.

Meanwhile, in the year 1781-2, Mr. Lavoisier, who had suspected that when oxygen and hydrogen gas are exploded, sulphuric or sulphurous acid is produced, made an experiment in order to ascertain the fact, at which Mr. Gengembre assisted. They filled a bottle, capable of holding six pints (French), with

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* Mem. Par. 1781, p. 470.

† Priestley, v. 395.

‡ Phil. Trans. lxxiv. 332.

§ Ibid. lxxv. 330.

hydrogen gas, to which they set fire, and then corked the bottle, after pouring into it two ounces (French) of lime-water. Through the cork there passed a copper tube, by means of which a stream of oxygen gas was introduced to support the flame. Though this experiment was repeated three times, and instead of lime water a weak solution of alkali and pure water were substituted, they could not observe any product whatever.* This result astonished Mr. Lavoisier exceedingly: he resolved, therefore, to repeat the experiment on a larger scale, and if possible with more accuracy. By means of pipes furnished with stop-cocks, he put it in his power to supply both gases as they should be wanted, that he might be enabled to continue the burning as long as he thought proper.

The experiment was made by Lavoisier and La Place on the 24th of June 1783, in the presence of Messrs. Le Roi, Vandermonde, several other academicians, and Sir Charles Blagden, who informed them that Mr. Cavendish had already performed it, and that he had obtained water.† They continued the inflammation till all their stock of gases was wasted, and obtained about 295 grains of water, which, after the most rigid examination, appeared to be perfectly pure. From this experiment Lavoisier concluded, that water is composed of oxygen and hydrogen. Mr. Mongez soon after performed the same experiment, and obtained a similar result: and it was repeated again by Lavoisier and Meusnier on a scale sufficiently large to put the fact beyond doubt.‡

This experiment has been so often repeated since, and has been varied in so many different ways, that it seems established beyond the reach of controversy. It appears therefore unnecessary to continue the history any farther, or to examine the objections brought forward by Dr. Priestley, as the opinions of that philosopher have no longer any supporters.

It was suspected soon after the original experiments of Mr. Cavendish that oxygen and hydrogen gases unite in the proportion of two volumes of hydrogen, and one volume of oxygen. But the experiments which first demonstrated the truth of these proportions with rigid accuracy, were those of Gay-Lussac and Humboldt. If the specific gravities which we have given of these two gases in the preceding book be accurate, then it follows that water is a compound of

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* Mem. Par. 1781, p. 470.

† Ibid. p. 472.

‡ Ibid. p. 474.

Oxygen	8
Hydrogen	1

So that the hydrogen in water amounts to $\frac{1}{9}$th of the weight, while the oxygen amounts to $\frac{8}{9}$ths of the weight of that liquid.

As for the *peroxide of hydrogen*, I have no additional facts to state to those given in the first volume of this work, while treating of *hydrogen*.

SECT. IV.

OF CARBONIC OXIDE.

History.

The substance at present known by the name of *carbonic oxide* is a gas which had been confounded with carburetted hydrogen, till Dr. Priestley drew the attention of chemists to it in a dissertation which he published in defence of the doctrine of phlogiston. His experiments were immediately repeated, and his opinions confirmed by Dr. Woodhouse of Pennsylvania. But the real nature and composition of the gas was discovered by Mr. Cruickshanks of Woolwich, and the discovery communicated to the public in 1802.* About the time of the publication of Mr. Cruickshanks' dissertation, the experiment of Woodhouse, which he had transmitted to France, drew the attention of the National Institute. Guyton Morveau, who had been appointed to give a detailed account of these experiments, engaged Clement and Desormes to investigate the subject; and these gentlemen were gradually led to the same conclusions† which had been previously drawn by Cruickshanks. The subject in the mean time attracted the attention of Berthollet, whose experiments induced him to form a different opinion respecting the composition of charcoal and carbonic oxide from that which had been entertained by the other chemists. This opinion he supported in three elaborate dissertations, published in the fourth volume of the Memoirs of the National Institute; in which he examines the experiments, and combats the conclusions, of the other chemists, with his usual sagacity. About the same time a dissertation was published by the Dutch chemists, contradicting the experiments of all other philosophers, and affirming the real results to be very different.‡ But the opinion of Cruickshanks gra-

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* Nicholson's 4to. Journal, v. 1 and 201.

† Ann. de Chim. xxxix. 88, and xlii. 121.

‡ Ibid. xliii. 113.

dually gained ground, chiefly in consequence of the experiments and publications of Dalton, and it seems now to be fully established.

Preparation.

I. There are four different processes by which carbonic oxide gas may be procured: First, When a mixture of purified charcoal and the oxides of iron or zinc, or indeed of any oxide capable of bearing a red heat, is exposed to a strong heat in an iron retort, the oxide is gradually reduced, and during the reduction a great quantity of gas is evolved. This gas is a mixture of carbonic acid gas and another which burns with a blue flame. It is to this last that the term *carbonic oxide* has been applied. The carbonic acid may be separated by passing the gas through lime-water. Mr. Cruickshanks tried in this way the oxides of iron, zinc, and copper, litharge, and the black oxide of manganese. The following conclusions result from his experiments: Those oxides which part with their oxygen most readily yield the greatest proportion of carbonic acid; those that retain their oxygen most obstinately yield the greatest proportion of carbonic oxide. It is always towards the beginning of the process that the greatest proportion of carbonic acid gas comes over; it gradually diminishes, and at last nothing but carbonic oxide is disengaged.* The results obtained by Clement and Desormes coincide almost exactly with the experiments of Cruickshanks. But they satisfied themselves with the white oxide of zinc, without trying those of other metals. They substituted plumbago for charcoal, and obtained the same results.†

Second, When a mixture of 1 part of purified charcoal, and 3 parts of the carbonate of lime, or of strontian, or of barytes, is exposed to a strong heat in an iron retort, the carbonic acid is gradually separated or decomposed, and gas is evolved in abundance. This gas consists of a mixture of about 1 part of carbonic acid to 5 parts of carbonic oxide.‡ In this case a portion of the carbonic acid of the carbonate is disengaged unaltered, but the greatest part of it is converted into carbonic oxide by the action of the charcoal.

Third, When a mixture of equal parts of any of the three above-mentioned earthy carbonates and clean iron filings is heated strongly in an iron retort, the carbonic acid is decomposed in like manner by the action of the iron, and the very

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* Nicholson's Jour. 1802, v. 2.

† Ann. de Chim. xxxix. 38.

‡ Clement and Desormes, Ann. de Chim. xxxix. 45.

same gases are procured in great abundance. Dr. Priestley first tried this method with the black oxide of iron and carbonate of barytes; but when Cruickshanks substituted pure iron, the gaseous product was considerably increased.[*]

Fourth, When carbonic acid gas is made to pass slowly and repeatedly through prepared charcoal heated to redness in a porcelain or iron tube, it gradually disappears, and carbonic oxide is found in place of it. Here the charcoal decomposes the carbonic acid precisely as in the two last cases, with this difference only, that it is in a gaseous state, whereas in them it was combined with a base. This experiment was first made by Cruickshanks,[†] and afterwards by Clement and Desormes.[‡]

How purified.

2. Such are the different processes for procuring carbonic oxide. From the experiments of Cruickshanks we learn, that the third method is the only one to be depended on for obtaining the gas in a state of purity. If equal parts of chalk and iron filings, previously exposed to a red heat separately in close vessels, be mixed together and strongly heated in an iron retort, the gases which come over are merely a mixture of carbonic acid and carbonic oxide; and the first being abstracted by means of lime-water, the carbonic oxide gas remains in a state of purity.

Properties.

3. Carbonic oxide gas, thus obtained, is invisible and elastic like common air. Its specific gravity, according to the experiments of Mr. Harvey, is 0·9700, that of air being 1·000. If we calculate the specific gravity on the supposition that it is composed of 1 volume of carbon and ½ volume of oxygen condensed into 1 volume, it will be 0·972.

Animals cannot breathe this gas without suffocation. Birds put into it by Desormes and Clement dropped down dead before they had time to take them out; and when they attempted to breathe it themselves, the consequence was giddiness and faintness.[§] Neither will any combustible body burn in it.

It is not altered by exposure to light, nor by passing it through a red-hot tube. From the experiments of Clement and Desormes, we find that it is dilated by heat exactly like common air, as was indeed to be expected.

Combustible.

4. Carbonic oxide gas is combustible. It takes fire in the open air, when it comes in contact with a red-hot body, or when it is presented to the flame of a candle, and burns with a lam-

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[*] Nicholson's Jour. 1802, v. 4 and 208.

[†] Ibid. p. 209

[‡] Ann de Chim. xxxix. 46

[§] Ibid. p. 56.

bent blue flame. When mixed with common air before it is kindled, it burns more rapidly and brilliantly, but does not detonate. The combustion is still more rapid and brilliant if we substitute oxygen gas for common air. Sometimes it detonates with oxygen, but most commonly the detonation does not take place.

Action of supporters,

II. The supporters of combustion act upon this gas in consequence of its combustibility.

Oxygen unites with it by combustion, in the proportion of 1 volume of oxygen to 2 volumes of carbonic oxide gas, and converts it into carbonic acid without altering its bulk.

Chlorine gas combines with it when the two gases are mixed and exposed to a strong light. The two gases combine in equal volumes, and the compound, by the union, is reduced to half its former bulk. This compound has the properties of an acid, and may be called *chlorocarbonic acid.*[*]

Iodine appears to have no action upon carbonic oxide.

Of combustibles.

III. The action of the simple combustibles on carbonic oxide has been but imperfectly examined.

1. According to Clement and Desormes, when a mixture of carbonic oxide and hydrogen gas is made to pass through a red-hot glass tube, charcoal is deposited, which lines the inside of the tube with a shining enamel; water is formed, and hydrogen, seemingly pure, disengaged from the other end of the tube.[†] But when this experiment was repeated by Saussure, junior, he found that the supposed enamel of charcoal was merely the black (or rather bluish) colour which flint glass acquires when hydrogen is brought in contact with it at a red heat, as had been previously observed by Dr. Priestley.[‡] Indeed it is very unlikely that hydrogen gas is capable of decomposing carbonic oxide; as Saussure has shown that, when carbonic acid and hydrogen gas are made to pass through a red-hot tube, the acid is decomposed, and carbonic oxide produced—a result which has been even confirmed by the subsequent experiments of Clement and Desormes.

2. When passed through red-hot charcoal, it dissolves a part of it, if we believe Desormes and Clement, and its specific gravity is increased.

3. When passed through melted sulphur, it does not com-

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[*] Its properties have been described in a former part of this work. See vol. i. p. 233.

[†] Ann. de Chim. xxxix. 61.

[‡] Jour. de Phys. lv. 396.

bine with it, nor alter its properties; but it dissolves a little phosphorus, and acquires the property of burning with a yellow flame.

4. The action of boron, silicon, arsenic, and tellurium, has not been examined.

5. Potassium and sodium have no immediate action on carbonic oxide gas at the ordinary temperature of the atmosphere. But when heated in it they take fire, and combine with the oxygen of the oxide, while the carbon is deposited.* Probably the metals of the alkaline earths and earths proper would likewise decompose this gas.

6. From any experiments hitherto made, it does not appear that carbonic oxide is capable of acting on the other metals: but Clement and Desormes affirm, that when passed hot over the red oxide of mercury, it produces a commencement of reduction. Indeed it is very likely that it will be found capable of reducing several of the metallic oxides, especially those that part with their oxygen easily.

Composition.

IV. From the experiments of Cruickshanks, Clement and Desormes, Dalton, and Gay-Lussac, there cannot be a doubt that this gas is a compound of carbon and oxygen; that it contains half the oxygen that exists in carbonic acid; and, therefore, that it is a compound of 1 atom carbon + 1 atom oxygen, or by weight of

Carbon	0·75	100
Oxygen	1·00	133·3

Besides the oxides described in this chapter, it is probable that both sulphur and phosphorus are capable of forming oxides which are destitute of acid properties. But no such compounds have been hitherto observed or described with any precision.

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* Gay-Lussac and Thenard; Recherches Physico-chimiques, i. 250.

Book II. Division I.

CHAP. II.

OF SALIFIABLE BASES.

The salifiable bases, or those bodies which have the property of neutralizing acids, are divisible into two sets; namely, 1. Combustible bases, and 2. Metallic oxides. The metallic oxides have been usually subdivided by chemists into four classes; namely, *fixed alkalies*, *alkaline earths*, *earths proper*, and *metallic oxides*. For the term, *metallic oxide*, in chemical books, is usually applied emphatically to the oxides of those metals which may be reduced without difficulty to the metallic state. Though this division is not quite accurate, it is attended with some advantages, which render it requisite for us to retain it. This chapter will therefore be divided into five sections. In the first of these, I shall give an account of the combustible bases, and in the last four of the fixed alkalies, alkaline earths, earths proper, and the metallic oxides.

SECT. I.

OF THE COMBUSTIBLE BASES.

The combustible bases at present known are six in number; namely,

Ammonia,
Morphia,
Strychnia,
Brucia,
Picrotoxia,
Delphia.

None of these have been hitherto accurately analysed, except the first, and perhaps also the second. But there is reason to believe that they all contain oxygen, except *ammonia*. Indeed they seem to bear the same relation to the other salifiable bases, that the combustible acids do to the incombustible acids. Though we have no satisfactory evidence that *ammonia* contains oxygen, it is so closely connected with the salifiable bases described in this chapter, that it cannot with propriety be separated from them.

I. AMMONIA.

Ammonia can be exhibited in a state of purity only under the form of a gas. It may be procured in the following manner:

Preparation.

1. Put into a retort a mixture of 3 parts of quick-lime and 1 part of sal ammoniac in powder. Plunge the beak of the retort below the mouth of a glass jar filled with mercury, and standing inverted in a basin of mercury. Apply the heat of a lamp to the retort: a gas comes over, which displaces the mercury and fills the jar. This gas is *ammonia*.

History.

Ammonia was altogether unknown to the ancients; the alchymists were acquainted with it, though not in a state of purity, being combined with carbonic acid, and often also dissolved in water. Basil Valentine describes the method of obtaining it. It was known by the name of *volatile alkali;* it was also called *hartshorn*, because it was often obtained by distilling the horn of the hart; *spirit of urine*, because it may be obtained by the same process from urine: and *spirit of sal ammoniac*, because it may be obtained from that salt. Dr. Black first pointed out the difference between ammonia and carbonate of ammonia, or ammonia combined with carbonic acid; and Dr. Priestley discovered the method of obtaining it in a state of purity, by the process described in the beginning of this Section.

Properties.

2. Ammonia in the state of gas is transparent and colourless like air; its taste is acrid and caustic like that of the fixed alkalies, but not nearly so strong, nor does it, like them, corrode those animal bodies to which it is applied: its smell is remarkably pungent, though not unpleasant when sufficiently diluted. Its use as a stimulant to prevent fainting is well known.

Animals cannot breathe it without death. When a lighted candle is let down into this gas, it goes out three or four times successively; but at each time the flame is considerably enlarged by the addition of another flame of a pale yellow colour, and at last this flame descends from the top of the vessel to the bottom.*

Its specific gravity is 0·590, that of common air being 1.

When exposed to a cold of − 45° it is condensed into a liquid, which again assumes the gaseous form when the temperature is raised.† When passed through a red hot tube of porcelain or glass, it is totally decomposed and converted into hydrogen and azotic gas.‡ That this experiment may succeed, the diameter of the tube must not be too great.

Liquid ammonia.

3. It combines very rapidly with water. When a bit of ice is brought into contact with this gas, it melts and absorbs the

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* Priestley, ii. 381.

† Morveau, Ann. de Chim. xxix. 292.

‡ Priestley, ii. 395.

Book II. Division I.

ammonia, while at the same time its temperature is diminished. Cold water absorbs this gas almost instantaneously, and at the same time heat is evolved, and the specific gravity of the water is diminished. Water, by my trials, is capable of absorbing 780 times its bulk of this gas; while, in the mean time, the bulk of the liquid increases from 6 to 10. The specific gravity of this solution is 0·900, which just accords with the increase of bulk. It is in this state that ammonia is usually employed by chemists. The term *ammonia* almost always means this liquid solution of ammonia in water. When heated to the temperature of about 130°, the ammonia separates under the form of gas. When exposed to the temperature of − 46° it crystallizes; and when suddenly cooled down to − 68°, it assumes the appearance of a thick jelly, and has scarcely any smell.*

It follows from the experiments of Davy, that a saturated solution of ammonia is composed of

74·63	water
25·37	ammonia
100·00	

The following table, for which we are indebted to Mr. Dalton, exhibits the quantity of ammonia contained in ammoniacal solutions of different specific gravities.†

Specific gravity of liquid.	Grains of ammonia in 100 water grain measures of liquid.	Grains of ammonia in 100 grains of liquid.	Boiling point of the liquid.	Volumes of gas condensed in a given volume of the liquid.
0·85	30	35·3	26°	494
0·86	28	32·6	38	456
0·87	26	29·9	50	419
0·88	24	27·3	62	382
0·89	22	24·7	74	346
0·90	20	22·2	86	311
0·91	18	19·8	98	277
0·92	16	17·4	110	244
9·93	14	15·1	122	211
0·94	12	12·8	134	180
0·95	10	10·5	146	147
0·96	8	8·3	158	116
0·97	6	6·2	173	87
0·98	4	4·1	187	57
0·99	2	2·	196	28

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* Fourcroy and Vauquelin, Ann. de Chim. xxix. 289.

† New System of Chemical Philosophy, ii. 422.

Action of electricity,

4. Ammoniacal gas is not altered by light; but when electric sparks are made to pass through it, the bulk of the gas is doubled, and it is converted into hydrogen gas and azotic gas.*

II. The supporters of combustion act with considerable energy upon ammonia, as might have been expected from its constituents.

Of oxygen,

1. When oxygen and ammoniacal gases are mixed, the mixture may be fired by an electric spark, as was first observed by Dr. Henry.† The mixture burns in all proportions, between 3 oxygen and 1 ammonia and 3 ammonia and 1·4 oxygen. When the oxygen is in excess the whole ammonia disappears, and a quantity of nitrate of ammonia is deposited. When the ammonia exceeds, the whole of it is decomposed by the explosion; part of its hydrogen unites to the oxygen and forms water while the rest remains mixed with the azote in the gaseous state. The proportion of these two gases may be determined by a subsequent detonation with oxygen. If it were possible to burn the whole of the hydrogen in the ammonia without touching the azote, 100 volumes of ammonia would require for complete combustion 75 volumes of oxygen, and the residue would consist of 50 volumes of azote. But it does not seem possible to remove the hydrogen without acting at the same time on the azote. Ammonia may be burnt in the same way.

Chlorine,

2. When pure ammoniacal gas is mixed with chlorine gas it takes fire and burns with a lively white flame, part of the ammonia is decomposed, the chlorine is converted into muriatic acid which unites with the undecomposed ammonia and is deposited in the form of sal ammoniac. Nothing remains but a quantity of azotic gas amounting to half the bulk of the decomposed ammonia. The same decomposition takes place when water holding chlorine in solution is mixed with liquid ammonia.

Iodine.

3. Iodine likewise decomposes ammonia though not with so much energy. One portion combines with the hydrogen of the alkali and is converted into hydriodic acid, while another portion uniting to the azote constitutes the iodide of azote.

Of combustibles.

III. The action of the simple combustibles on ammonia has been but imperfectly examined.

1. Hydrogen, as might have been expected, produces no change on it whatever.

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* Priestley, ii. 389.

† Phil. Trans. 1809.

2. Charcoal absorbs ammoniacal gas, but does not alter its properties while cold. But when the gas is made to pass through red-hot charcoal, part of the charcoal combines with it and forms the substance known by the name of *prussic acid*,* or hydrocyanic acid.

3. We are not acquainted with the action of boron and silicon.

4. Phosphorus produces no change on ammoniacal gas while cold; but when this gas is made to pass through phosphorus in a red-hot porcelain tube, it is decomposed, and phosphuretted hydrogen gas formed.†

Sulphuret.

5. It combines with sulphur in the state of vapour, and forms a sulphuret which decomposes water, and forms *hydroguretted sulphuret of ammonia*, known formerly by the name of *fuming liquor of Boyle*, because it was first described by that philosopher.‡ It is commonly prepared by distilling a mixture of 5 parts of sal ammoniac, 5 parts of sulphur, and 6 of quicklime. It is a liquid of a red or rather deep orange colour, and exhales a fetid odour, in consequence of an excess of ammonia which it contains. Its nature was first pointed out by Berthollet.§

6. When potassium or sodium is heated in ammoniacal gas, the metal is converted into an olive-green matter, quite destitute of the metallic lustre, while at the same time a portion of the ammoniacal gas is absorbed and a quantity of hydrogen emitted, exactly equal to the quantity that would be evolved if the potassium or sodium were put into water. If the olive-green matter be heated, it gives out $\frac{3}{5}$ths of the ammonia absorbed, $\frac{2}{5}$ths in the state of ammoniacal gas, and $\frac{1}{5}$th in the state of hydrogen gas and azote. Sir Humphrey Davy, having heated the olive-coloured matter strongly in a platinum tube, obtained nearly the whole of the ammonia absorbed; though about $\frac{3}{5}$ths of it was in the state of azotic and hydrogen gas. If the olive-coloured matter be placed in contact with a very little water, it is converted into potash or soda and ammoniacal gas, and the gas is just equal to what the metal had absorbed. If it be placed in contact with a metal and heated, an alloy of the metal with potassium or sodium is obtained.

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* Scheele, ii. 183; and Clouet, Ann. de Chim. xi. 30.

† Fourcroy, ii. 237.

‡ Shaw's Boyle, ii. 78.

§ Ann. de Chim. xxv. 233.

For these curious facts we are indebted to Gay-Lussac and Thenard,[*] and Davy. They seem to me to show that potassium and sodium have the property of decomposing ammonia and combining with its azote, while the hydrogen of the ammonia is set at liberty. The azoturet formed it would seem is capable of absorbing and uniting with a portion of undecomposed ammonia. When water is placed in contact with this azoturet it is decomposed, its oxygen converts the potassium into potash, while its hydrogen converts the azote into ammonia.

There is one circumstance however which cannot be reconciled to this simple explanation of the phenomena. Water is a compound of *two* volumes hydrogen and *one* volume oxygen, whereas ammonia is a compound of *three* volumes hydrogen and *one* volume azote. Now since the potassium disengages from the ammonia exactly as much hydrogen as it does from water, it is obvious that it can deprive the ammonia of only 2 volumes of hydrogen, so that 1 volume of hydrogen and 1 volume of azote must remain to enter into combination with the potassium. What the nature of this substance (composed of 1 atom azote + 1 atom hydrogen) is we cannot say, as it has never been obtained in a separate state. But that it is this unknown substance and not pure azote which enters into combination with the potassium appears to follow irresistibly from the phenomena.

Of metals.

7. Ammonia does not appear capable of combining with any of the metals; but it changes some of them into oxides and then dissolves them. The oxidizement is evidently in consequence of the decomposition of part of the water with which the ammonia is combined; for hydrogen gas is emitted during the solution. Copper and zinc are oxidized by the action of ammonia; as are also tin and iron, though only superficially. Scarcely any of the other metals are altered by its action.

Dissolves metallic oxides.

Liquid ammonia is capable of dissolving the oxides of silver, copper, iron, tin, nickel, zinc, bismuth, and cobalt.[†] When digested upon the oxides of mercury, lead, or manganese, it is decomposed, water is formed, by the union of the hydrogen of the ammonia with the oxygen of the oxides, and azotic gas is emitted.[‡] If a considerable heat be applied, nitric acid is

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[*] Recherches Physico-chimiques, i. 337.

[†] It dissolves the protoxide of iron when added in excess, but only in small quantities. The peroxide of iron is insoluble in it; so is the peroxide of cobalt, according to Thenard.

[‡] Scheele.

formed at the same time with water.* Several other oxides are also partly deoxidized when ammonia is poured into their solutions in acids. The ammoniacal solution of the peroxide of copper is of a fine blue colour, and, according to Sage, capable of crystallizing. When heat is applied, the ammonia is partly driven off, and partly decomposed, by the combination of its hydrogen with the oxygen of the oxide.

IV. Ammonia combines readily with the oxides of gold, silver, and platinum, and forms compounds, known by the names of *fulminating gold, fulminating silver,* and *fulminating platinum;* because, when heated or rubbed, they explode with great violence. It forms a similar compound with the red oxide of mercury.

Fulminating gold.

Fulminating gold may be prepared by dissolving gold in nitro-muriatic acid, diluting the solution with thrice its weight of water, and then dropping in pure ammonia by little and little as long as any precipitate is formed; taking care not to add too much, because in that case part of the precipitate is again dissolved. The precipitate, which is of a yellow colour, is to be washed in pure water, dried slowly upon filtering paper, and then put into a phial: which, to prevent accidents, ought not to be corked, but its mouth covered with a linen rag or a slip of paper. This powder is fulminating gold; which is composed of 5 parts of yellow oxide of gold and 1 part of ammonia.† The preparation of this powder is described by Basil Valentine; and its singular properties excited the attention of all succeeding chemists. Various attempts were made to account for its fulminating property, but without success, till Bergman published his dissertation on it in 1769. He demonstrated, that it is a compound of ammonia and yellow oxide of gold: that during its explosion the oxide is reduced, the ammonia decomposed, and the azote, which it contained, set at liberty in the form of gas.‡ These facts (partly discovered by Scheele) led him to explain the explosion as follows: Ammonia is composed of azote and phlogiston. When heat is applied to fulminating gold, the phlogiston combines with the oxide, and forms gold, while the azote flies off in the form of gas. The experiments of Bergman and Scheele were repeated and confirmed by Berthollet in 1786; and the nature of oxides having been previously ascertained by

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* Milner, Phil. Trans.—Fourcroy, v. 355.

† Bergman, ii. 155.

‡ Bergman, ii. 153; and Scheele on Fire, 137.

Lavoisier, he was enabled to give a more satisfactory explanation of the phenomena. During the explosion, the hydrogen of the ammonia combines with the oxygen of the oxide, and forms water; the gold is reduced, and the azote evolved in the form of gas. The great expansibility of this gas by heat explains the violence of the explosion.

Fulminating gold explodes when struck violently, or when triturated in a mortar, or when heated to a temperature of about 400°.* The noise is tremendous; and when in any considerable quantity (12 grains for instance) it lacerates the metallic plate on which it is placed. When heated in close vessels, sufficiently strong to resist its action, it is reduced silently, and without any marks of violence.† Its force was compared with that of gunpowder by the Royal Society, but found inferior.

Fulminating silver.

Fulminating silver was discovered by Berthollet in 1788. It may be formed by dissolving very pure silver in nitric acid, and then precipitating it by lime water. The precipitate is put upon filtering paper, which absorbs the water and the nitrate of lime with which it was mixed; then pure liquid ammonia is poured upon it, and allowed to remain for 12 hours; it is then decanted off, and the black powder, on which it stood, is placed cautiously, and in very small portions, upon bits of filtering paper. This powder is fulminating silver. Even while moist it explodes with violence when struck by a hard body. When dry, the slightest touch is sufficient to cause it to fulminate. When the liquid decanted off this powder is heated in a glass retort, an effervescence takes place, azotic gas is emitted, and small crystals make their appearance, which are opaque, and have a metallic brilliancy. These fulminate when touched, even though covered by the liquid, and often break in pieces the vessels in which they are kept.‡

The theory of this dangerous powder is the same as that of fulminating gold. It is a compound of ammonia and oxide of silver. Friction, or the application of heat, occasions the combination of the oxygen of the oxide with the hydrogen of the ammonia: water is formed, the silver is reduced, and azotic gas emitted.

Fulminating platinum.

Fulminating platinum has been lately discovered by Mr. Edmund Davy. His process is as follows: Platinum is precipitated from its solution in nitro-muriatic acid, by means of

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* Edmund Davy.

† Bergman, ii. 141.

‡ Berthollet, Ann. de Chim. i. 54.

sulphuretted hydrogen. The precipitate is digested in nitric acid till it is converted into sulphate of platinum. This sulphate, being dissolved in water, is precipitated by ammonia, and the precipitate, being washed, is put into a Florence flask with potash ley, and boiled for some time. Being now separated by the filter, washed, and dried, it constitutes fulminating platinum. It is a brown powder, specifically lighter than fulminating gold. It explodes violently when heated to 400°, but cannot be exploded by trituration or percussion. It is a non-conductor of electricity. It dissolves in sulphuric acid, and the solution is very deep-coloured. Nitric acid has but little action on it. Chlorine and muriatic acid gas decompose it. According to Mr. E. Davy, it is composed of

Tritoxide of platinum	82·5
Ammonia	9·0
Water	8·5

Numbers which approach 2 atoms of tritoxide, 1 atom of ammonia and 2 water.

Ammoniacal fulminating mercury.

Ammoniacal fulminating mercury was discovered by Fourcroy. It may be formed by digesting a strong solution of ammonia in water upon the red oxide of mercury. After the process has continued for eight or ten days, the oxide assumes a white colour, and is at last covered with small crystalline scales. In this state it detonates loudly upon ignited coals in the same manner as fulminating gold. It loses its fulminating property, and undergoes spontaneous decomposition in a few days. When exposed to a low heat, the ammonia is driven off, and the red oxide assumes its former appearance.*

Such is the explanation of these compounds, deduced from the phenomena which they have been observed to exhibit. But it is to be wished that some modern chemist would subject them to a more rigid examination. From the facts known respecting the chloride and iodide of azote, it would not be surprising if fulminating gold and silver were of a similar nature, consisting simply of these metals united to azote. It is probable that a class of bodies called *azoturets* may exist, and that they are of a fulminating nature, in consequence of the ease and rapidity with which the azote recovers its elastic form.

Composition of ammonia.

V. As ammonia has the property of detonating with nitre, chemists had unanimously agreed that it contains phlogiston. Scheele first demonstrated, that when it is decomposed by

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* Journals of the Royal Institution, i. 256.

means of the oxide of manganese, arsenic, or gold, azotic gas is set at liberty, while the oxide is reduced.* Hence he concluded, that it is composed of azote and phlogiston; and Bergman coincided with him in opinion. Dr. Priestley discovered, that when electric explosions are made to pass through this gas, its bulk is gradually augmented to thrice the space which it formerly occupied; and a quantity of hydrogen gas is produced. The same ingenious philosopher applied heat to the red oxides of mercury and lead confined in ammoniacal gas. The oxides were reduced, water was evolved, the ammoniacal gas disappeared, and instead of it, there was found a quantity of azotic gas.† These experiments, and those of Scheele, led to the conclusion, that ammonia is composed of azote and hydrogen; a conclusion which was fully established by the experiments of Berthollet, published in the Memoirs of the French Academy for 1785. This acute philosopher repeated the experiments of Scheele and Priestley, and applied to them the theory of Mr. Lavoisier, and added also several very decisive ones of his own.

A great many experiments have been made on the composition of ammonia, chiefly in consequence of the opinion advanced by Sir Humphrey Davy, that oxygen was one of its constituents—an opinion, however, that was not supported by the subsequent experiments of chemists, and which he accordingly abandoned. The following table exhibits the results of the most accurate analyses of this substance hitherto made:

	Volumes.			Volumes.	
Berthollet, senior ‡	72·5	hydrogen	+	27·5	azote.
Berthollet, junior §	75·5	....	+	24·5	
Henry ‖	73·75	....	+	26·25	
Davy **	74	....	+	26	
Gay-Lussac ††	75	....	+	25	

Gay-Lussac's proportions are rather the result of calculation than of actual experiment. But the results of Berthollet, junior, on the one hand, and those of Davy and Henry on the other, approach so closely to it, that we cannot hesitate to adopt his numbers as the true proportions. Ammonia then is composed of 3 volumes of hydrogen and 1 volume of azote; or, which comes in this case to the same thing, of 3 atoms

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* Scheele, i. 95 and 155, French Trans.—Scheele on Fire, p. 137.

† Priestley, ii. 396.

‡ Mem. Paris, 1785.

§ Mem. d'Arcueil, ii. 268.

‖ Phil. Trans. 1809.

** Phil. Trans.

†† Mem. d'Arcueil, ii. 253.

hydrogen and 1 atom azote. Hence its constituents by weight are

Hydrogen	0·125 × 3 = 0·375	100
Azote	1·75	466·6

And the weight of an atom of ammonia is 2·125.

Supposed an oxide.

VI. It must not be concealed, however, that there is a very curious experiment, for which we are indebted to Berzelius and Pontin, from which Berzelius has drawn, as a conclusion, that ammonia consists of an unknown metallic basis, to which he has given the name of *ammonium*, united to oxygen. This experiment was repeated and verified by Sir H. Davy, and the subject was afterwards examined with much care by Gay-Lussac and Thenard. The experiment is as follows:

And its base a metal.

Mercury, at the negative end of a galvanic battery, is placed in contact with a solution of ammonia, and the circuit completed. It gradually increases in volume, and, when expanded to four or five times its former bulk, becomes a soft solid. The experiment is easier, and the amalgam more permanent, if sal ammoniac slightly moistened be substituted for liquid ammonia. Davy made a cavity in a piece of sal ammoniac slightly moistened, placed it on a plate of platinum attached to the positive end of the galvanic battery, put into the cavity about 50 grains of mercury, and brought in contact with the mercury a platinum wire attached to the negative end of the battery. A strong effervescence took place, much heat was evolved, and the globule in a few minutes had enlarged to five times its original bulk, and had the appearance of an amalgam of zinc. This amalgam, at the temperature of 70° or 80°, is a soft solid of the consistence of butter; at 32° it is a firm crystallized mass in which small facets appear, but having no perfectly defined form. Its specific gravity is below 3. When exposed to air it soon becomes covered with a white crust of carbonate of ammonia. When thrown into water, a quantity of hydrogen is evolved equal to half its bulk, the mercury is revived, and the water becomes a weak solution of ammonia. When confined in a given portion of air, the air increases considerably in volume, and pure mercury reappears. Ammoniacal gas amounting to $1\frac{1}{2}$ or $1\frac{3}{5}$, the volume of the amalgam is evolved, and a quantity of oxygen equal to $\frac{1}{7}$th or $\frac{1}{8}$th of the ammonia disappears. When thrown into muriatic acid gas it becomes coated with muriate of ammonia, and a little hydrogen is disengaged. In sulphuric acid it becomes coated with sulphate of ammonia and sulphur. All attempts made by Davy to preserve this amalgam failed, owing to the impossibility of freeing it entirely of water. When put into a glass tube, or when confined under naphtha or oils, the mercury separated, ammonia was formed, and a quantity of hydrogen evolved.*

The result of the experiments of Gay-Lussac and Thenard is, that this amalgam is a simple combination of mercury and ammonia. But we are not able to form such a combination by any other method than the one just described. Nor do we know any example of mercury being capable of amalgamating with any substance except a metal. When it unites with other bodies, as oxygen, sulphur, oils, &c. it always loses its metallic lustre. These reasons induce Berzelius to conclude that the amalgam is a compound of mercury and the metallic basis of ammonia. The reason why it cannot be preserved he conceives to be that the mercury contains a little moisture which speedily converts the ammonium to ammonia by supplying it with oxygen.

I consider the strongest evidence to lie on the side of the opinion of Gay-Lussac and Thenard. But the subject requires farther investigation. If it be true that ammonia can amalgamate with mercury, we must alter the presently received notions respecting amalgams.

II. MORPHIA.

Opium.

The substance called *opium* is a milky juice, obtained by incisions from the unripe seed vessels of the *papaver somniferum*. It speedily becomes solid, and assumes the dark brown colour by which opium is characterized. In the east this substance has been used from time immemorial as an intoxicating drug. In Europe it was first introduced as a medicine by Paracelsus, and it constitutes one of the precious articles in the materia medica. Many attempts were made by chemists and apothecaries to determine the constituents of this substance. But the first steps of any importance were made by Derosne in 1803.† He obtained from it a transparent and colourless substance crystallized in four sided prisms with rhomboidal bases. It is destitute of taste and smell, insoluble in cold water, but soluble in hot water and in alcohol, and very readily soluble in all the acids. This substance was found to possess the intoxicating and poisonous qualities of opium, and

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* Davy's Electro-chemical Researches on the Decomposition of the Earths, &c. Phil. Trans. 1808.

† Ann. de Chim. xlv. 287.

was in consequence considered as the *narcotic principle.* Derosne observed too, that when potash was poured into the infusion of opium a copious precipitate falls, and that this precipitate possesses the property of acting upon vegetable blues after the manner of an alkali, a property which he ascribed to the presence of a little potash, which, in his opinion, the precipitate still retained.

Discovery. In the year 1817 M. Sertuerner, apothecary at Eimbeck, in Hanover, published the result of his experiments on opium, which had occupied his attention for several years.[*] When ammonia is poured into the infusion of opium a white precipitate falls, consisting chiefly of a substance to which Sertuerner gave the name of *morphia*,[†] and which he found capable of neutralizing acids. He therefore gave it the name of an alkali. His experiments have been since repeated and confirmed by Robiquet,[‡] Choulont,[§] Pelletier and Caventou,[||] and by various other chemists both on the continent and in Great Britain.

How obtained. I. Three different processes have been given for procuring morphia, the two first of which I have repeated with success.

1\. Sertuerner's formula is as follows. Rub 8 ounces of pulverized opium with two or three ounces of concentrated acetic acid and a little water to the consistence of a soft paste. Dilute this paste with three or four pounds of water, and strain it through a cloth; the residue may be washed with a little water and strained a second time. The liquid thus obtained is but little coloured. When caustic ammonia is poured into it morphia is precipitated in abundance. If the liquid be evaporated to a fifth of its bulk an additional quantity of morphia will be obtained. But the morphia thus procured is still contaminated with extractive. To purify it, Sertuerner digested it in a small quantity of cold alcohol, by which the greatest part of the extractive is dissolved. The morphia thus purified is dissolved in boiling alcohol and obtained in the state of crystals as the liquid cools.

2\. Robiquet employed the following method to procure morphia. He boiled a concentrated aqueous solution of opium with a small quantity of magnesia (1 grain of magnesia to 49

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[*] Gilbert's Annalen der Physick, lv. 56.

[†] Sertuerner in fact called it *morphium*, *um* being the termination adopted for the alkalies in German. The French have called it *morphine*. As the English termination for the alkalies is *a*, we must of course employ the word *morphia*, as I have done in the text.

[‡] Ann. de Chim. et de Phys. v. 275.

[§] Gilbert's Annalen, lvi. 342.

[||] Jour. de Pharmacie, v. 538.

grains of opium is sufficient) for a quarter of an hour. A copious grey precipitate fell. This precipitate was separated by the filter and washed, first in cold water and afterwards macerated for some time in weak alcohol, warm, but not boiling hot. By this means the greatest part of the colouring matter was separated. The matter thus purified was washed with cold alcohol. It was then dissolved by continued boiling in concentrated alcohol. The boiling liquid was filtered, and on cooling it deposited morphia in crystals nearly free from colour.

3. Choulant's process is as follows. Four ounces of well dried and pounded opium were digested in repeated quantities of cold distilled water till the liquid amounted to the quantity of about 16 English pints. This infusion was evaporated by a gentle heat on the sand bath in a glass vessel till it was reduced to 8 ounces. The whole was then poured into a porcelain evaporating dish. After standing at rest for eight hours in a temperature between 54° and 77°, six grains of small crystals were deposited, which possessed the characters of sulphate of lime. The whole being evaporated to dryness was redissolved in distilled water, with the exception of a small quantity of brownish coloured resin. Oxalate of ammonia being dropped into the solution it became muddy, and a precipitate fell, which weighed when dry 3¼ grains. After this precipitate was separated muriate of barytes was added as long as it occasioned a precipitate. This last precipitate being separated and dried weighed 2 grains. The solution was now diluted with 8 pints of distilled water and caustic ammonia poured into it as long as any precipitate continued to fall. The precipitate thus obtained was white and flocky. After standing 2 hours it became granular and brown. It weighed 6 drams. It dissolved completely in 8 ounces of distilled vinegar, and was precipitated by caustic ammonia without any alteration in its colour or its weight. Upon this precipitate one ounce of sulphuric ether was poured. The mixture swelled up considerably. It was thrown upon a white paper filter. In the course of half an hour a deep black liquid ran through, which weighed half an ounce, had a strong ammoniacal smell, burned very readily, and left a bulky charcoal behind it. The matter remaining upon the filter had a frothy appearance; but when dry it was in the state of a very fine powder and had lost much of its dark colour. It now weighed 4⅔ drams. This powder was digested three times in caustic ammonia, and as often in alcohol. Both of these li-

quids acquired a dark brown colour, and left the morphia in the state of a brownish white powder reduced to the weight of three drams. This powder was dissolved in 12 ounces of boiling alcohol. The filtered solution being set aside for 18 hours deposited colourless, transparent crystals, which weighed 75 grains, and consisted of morphia in a state of purity. By evaporating the alcohol an additional quantity of morphia was obtained, but it was not quite pure.*

Properties.

II. Morphia thus obtained is transparent and colourless, and crystallized in four sided pyramids with square or rectangular bases. Sometimes the crystals are octahedrons composed of two of these pyramids applied base to base. Its taste is very bitter and astringent; and when swallowed it produces the same effects as opium itself; but it acts much more powerfully when in a state of solution; and when in the solid state it scarcely produces any effect, owing to the little action of the juices of the stomach on it. The vegetable acids, particularly vinegar, have the property of most powerfully counteracting its poisonous effects, no doubt by neutralizing it.†

Solubility.

Water, at the boiling temperature, dissolves the 82d part of its weight of morphia, and the solution on cooling deposits regular, colourless, transparent crystals. It is soluble in 36 times its weight of boiling alcohol, and in 42 times its weight of cold alcohol. It is soluble in 8 times its weight of sulphuric ether.‡

All these solutions redden turmeric paper, restore the blue colour of litmus paper reddened by vinegar, change the infusion of Brazil wood to violet, and the tincture of rhubarb to brown. When the solutions of morphia in alcohol and ether are rubbed upon the skin they leave a red mark.

Morphia melts in a gentle heat, and in that state has very much the appearance of melted sulphur. On cooling it again crystallizes. It burns easily, and when heated in close vessels leaves a solid, resinous, black mass, having a peculiar smell. It combines with sulphur by the assistance of heat. But the combination is speedily destroyed and sulphuretted hydrogen evolved.§

It combines with the different acids, neutralizes them completely, and forms salts which are mostly soluble in water and capable of crystallizing. Some attempts have been made to

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* Annals of Philosophy, xiii. 153.

† Orfila, Ann. Chim. et de Phys. v. 288.

‡ Choulant.

§ Sertuerner.

determine the composition of these salts, but in all probability the results hitherto laid before the public are not entitled to much confidence. A single specimen will be sufficient to show the discordance between the analyses of different chemists.

Composition.

According to Robiquet, 38·61 grains of morphia just saturated 6·95 grains of sulphuric acid.* Now 6·95 grains of sulphuric acid, of the specific gravity 1·845, contain 5·67 grains of real acid. Hence, according to this experiment, sulphate of morphia is composed of

Sulphuric acid	5·67	5
Morphia	38·61	34·047

According to Choulant the constituents of sulphate of morphia † are as follows:

Sulphuric acid	22	5
Morphia	40	9·09
Water	38	
	100	

According to the experiments of Pelletier and Caventou, the constituents of this salt are ‡

Sulphuric acid	11·084	5
Morphia	88·916	40·112
	100·000	

Thus the equivalent number for morphia, according to Robiquet, is 34; according to Choulant, it is 9; and, according to Pelletier and Caventou, it is above 40. If we were to add the water given by Choulant in his analysis to the morphia, and consider it as a constituent part of it, then the equivalent number in his analysis for morphia would become 17·72. Now the mean of the analyses of Robiquet and Pelletier and Caventou gives 37·08. But 17·728 × 2 = 35·456, which approaches 37·08. Were we therefore to consider Choulant's salt as a bisulphate of morphia, the equivalent number for morphia derived from these three analyses will be 36·538.

To be able to form some estimate of the relative value of these analyses, I heated 1 grain of morphia in a copper tube with a sufficient quantity of peroxide of copper. I obtained 3·58 cubic inches of carbonic acid gas, and a quantity of water indicating 2·62 cubic inches of hydrogen. Hence the carbon and the hydrogen present in 1 grain of morphia weigh

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* Ann. de Chim. et de Phys. v. 280. † Annals of Philosophy, xiii. 151.

‡ Jour de Pharmacie, v. 536.

0·5083 grain. The deficiency equal to 0·4917 grain I consider as oxygen, and this weight of oxygen is equivalent to 1·45 cubic inch of oxygen gas. Now the smallest number of atoms which will correspond with these proportions is as follows:

18 atoms hydrogen ... =	2·25	5·59
24 atoms carbon ...... =	18·00	44·72
20 atoms oxygen ..... =	20·00	49·69
	40·25	100·00

According to this analysis (which must be very near the truth) morphia is a compound of no fewer than 62 atoms, and the weight of an integrant particle of it is 40·25. This comes very near the number resulting from the analysis of sulphate of morphia by Pelletier and Caventou. Hence I am led to consider their analysis as very near the truth.

III. STRYCHNIA.

Discovery.

This new alkaline substance was discovered in the year 1818 by MM. Pelletier and Caventou in the fruit of three different species of *strychnos*, namely *strychnos nux vomica*, *strychnos ignatia* and *strychnos columbrina*. The first of these fruits has been long known in this country under the name of *nux vomica*, the second has been distinguished by the name of St. Ignatius bean, but the third has been too little known in Great Britain to be distinguished by a particular name, the wood of the tree which bears it has been long known under the name of *snake-wood*. These trees are natives of India. The nux vomica has been occasionally used in medicine as a remedy in mania, epilepsy, &c. and particularly in obstinate cases of intermittent fever. But in Great Britain, at least, it is scarcely ever employed by modern physicians.

The nux vomica is a round compressed seed, very hard and scarcely capable of being triturated to powder in a mortar. Strychnia was extracted from it by Pelletier and Caventou in the following manner. It was digested in alcohol and the alcoholic solution, which is deep coloured, was evaporated to dryness, and the dry residue dissolved in water. Into this aqueous solution Goulard's extract (*subtritacetate of lead*) was dropped as long as a precipitate continued to fall. By this process the acid with which the strychnia is combined, the fatty matter, and the greatest part of the colouring matter in the liquid were precipitated while the strychnia remained in solution, combined with the acetic acid of the salt of lead employed. A current of sulphuretted hydrogen gas was now passed through the filtered liquid to throw down any excess of lead that might have been introduced. To the filtered liquid magnesia was added, and the mixture was boiled. The strychnia was precipitated while the magnesia took its place, and united with the acetic acid. The precipitate was washed in cold water, and then dissolved in alcohol to separate any excess of magnesia with which it might have been mixed. By evaporating the alcoholic solution the strychnia was obtained in a separate state. If by this process it is not brought to the requisite purity, it may be again redissolved in acetic or muriatic acid precipitated by magnesia and redissolved in alcohol. By this method it may be at last brought to a state of complete purity.

Properties.

Strychnia* thus obtained is a white substance, either granular, or in very small four sided prisms, terminated by low four sided pyramids. It has no smell; but its taste has an insupportable bitterness, leaving a kind of metallic impression in the mouth. When exposed to the air it undergoes no change. It is neither fusible nor volatile at any temperature below that at which it undergoes decomposition, which seems to be about 600°, for when exposed to the temperature of boiling olive oil it is charred. When strongly heated it swells, blackens, gives out a little empyreumatic oil, some water, and acetic acid, inflammable gas, and carbonic acid gas, and a very bulky charcoal remains behind. When heated with peroxide of copper it is totally converted into carbonic acid and water. Hence it is composed of carbon, hydrogen, and oxygen in proportions not yet determined.

Solubility.

It is very imperfectly soluble in water; that liquid, at the temperature of 50°, dissolving only $\frac{1}{6667}$th of its weight of it, while 1 part of it dissolves in 2500 parts of boiling water. When the solution of it in cold water is mixed with 100 times its weight of that liquid, it still retains a very sensible bitter taste. In alcohol, on the contrary, it is exceedingly soluble.

It restores the blue colour of litmus paper, reddened by an acid, does not redden turmeric paper; but combines with the different acids which it neutralizes completely, forming salts, most of which are capable of crystallizing.

Action of nitric acid.

When concentrated nitric acid is poured upon strychnia, especially if heat be applied, the colour of the substance is changed into an intense blood red; and by a longer continued

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* Pelletier and Caventou give to this substance the name of *strychnine*, which I have changed into *strychnia* for the reason assigned in page 38.

Book II. Division I.

action of the acid the colour becomes yellow. It would appear probable, from the experiments related by Pelletier and Caventou, that these changes of colour are owing to the combination of a portion of oxygen with the strychnia. When potash is added to the red liquid produced by the action of nitric acid on strychnia, an orange coloured precipitate falls, provided the liquid be somewhat concentrated. This precipitate is strychnia somewhat altered in its properties. It still acts as an alkali; but not so powerfully as the unaltered strychnia. When the yellow coloured solution of strychnia in nitric acid is treated with magnesia, a precipitate is likewise obtained which acts as an alkali; but still more feebly than the orange coloured precipitate.

Oxygen has no sensible action on strychnia, at least in the common temperature of the atmosphere. When a current of chlorine gas is passed through water mixed with strychnia, the alkaline substance dissolves, and when the liquid is allowed to evaporate spontaneously, crystals of muriate of strychnia make their appearance. If the liquid be exposed to the action of heat, instead of being allowed to evaporate spontaneously, it assumes a brown colour. Probably both chlorate and muriate of strychnia have been formed, and the brown colour is owing to the decomposition of the former salt by the action of heat.

When iodine and strychnia are boiled together in water, a colourless solution is obtained, which, when evaporated, yields colourless and transparent crystals of iodate of strychnia. The liquid contains in solution hydriodate of strychnia. To convert the whole of the iodine into iodic and hydriodic acids, we must employ a greater proportion of strychnia than can be dissolved, and separate it after the solution of the iodine by the filter. When iodine and strychnia, mixed with a very small quantity of water, are made to act on each other, the strychnia becomes red just as when acted upon by nitric acid.

Sulphur does not act upon strychnia when boiled with it in water. But if the two substances be heated together, without any water, till the sulphur melts, a great quantity of sulphuretted hydrogen gas is disengaged. Carbon has no sensible action on strychnia. It is insoluble in the fixed oils and in ethers, but dissolves readily in the volatile oils.

Action on living beings.

Strychnia acts with great violence upon living beings. About half a grain of it is sufficient to destroy the life of a rabbit. Convulsions are induced, and the animal dies in about five minutes in consequence of a violent attack of tetanus. The same effects take place when the strychnia is introduced into a wound. Morphia seems to diminish the violence of the action of this poison; but not to destroy its effects. Thus it would appear that strychnia acts as a very powerful stimulant. The salts of strychnia act with more energy than the alkaline substance itself.*

Equivalent number for.

From the analysis of Pelletier and Caventou, it appears that the constituents of sulphate of strychnia are as follows:†

Sulphuric acid	9·5	5
Strychnia	90·5	47·621
	100·0	

From this analysis we see that the equivalent number for strychnia is 47·621.

IV. BRUCIA.

Discovery.

This new alkaline substance was discovered by Pelletier and Caventou in 1819, in the bark of the *Brucæa Antidysenterica*. This bark had been introduced into medicine as a substitute for *angustura*, and had been distinguished by the name of *false angustura*. The Brucæa was named from Bruce, the Abyssinian traveller, who first brought the seeds of the tree from Abyssinia, and they afterwards vegetated in the botanical gardens of Europe.

Brucia was obtained in a separate state by Pelletier and Caventou, by the following process.

How obtained.

The bark was deprived in the first place of its fatty matter by means of sulphuric ether. It was then digested in alcohol, the alcoholic solution was evaporated to dryness, the dry residue redissolved in water, and the aqueous solution treated with subtritacetate of lead to throw down the colouring matter. The filtered liquor was exposed to a current of sulphuretted hydrogen gas to throw down the excess of lead, and then filtered. The liquor thus purified was neither precipitated by ammonia, carbonate of potash, nor magnesia. But the addition of these substances developed alkaline characters even when they were used only in such quantities as to saturate the acid that existed in the liquid. To obtain the brucia which constituted the alkaline portion of the liquid, it was saturated with oxalic acid, and the liquid was evaporated to dryness. Absolute alcohol at the temperature of 32° was digested upon it, which dissolved all the other substances

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* Pelletier and Caventou, Jour. de Pharmacie, v. 173.

† Ibid. p. 536.

present except the oxalate of brucia, which remained behind in the state of a white salt. When this salt was treated with lime, it was decomposed; boiling alcohol dissolved the brucia, and the liquid when evaporated deposited the alkali in the state of small crystals.

Properties.

Brucia thus obtained has the form of four-sided oblique prisms, with parallelograms for their bases. When obtained by decomposition from a saturated boiling alcoholic solution, it has the form of pearly scales, similar in appearance to boracic acid. These scales are very light, containing a great deal of water between them. Hence the bulk diminishes exceedingly when they are compressed.

Its taste is very bitter with a certain degree of acridity, which remains long in the mouth. It is soluble in 500 times its weight of boiling water, and in 850 times its weight of cold water. The colouring matter which exists in the bark adds greatly to its solubility.

It is not altered by exposure to the air. When raised to a temperature somewhat higher than the boiling point of water, it melts and assumes on cooling the appearance of wax. Exposed to a strong heat it is decomposed, yielding a great deal of empyreumatic oil, a little water and acetic acid, carburetted hydrogen gas, and a very small proportion of carbonic acid gas. When heated with peroxide of copper it is converted into carbonic acid and water. Hence its constituents are carbon, hydrogen, and oxygen in unknown proportions.

It neutralizes the acids and forms salts, the greater number of which are soluble in water, and crystallize in a determinate form.

When treated with concentrated nitric acid, it assumes a red and then a yellow colour in the same way as strychnia; but the shades of colour are different from those formed by that alkaline substance. These changes are probably owing to the addition of oxygen, which induces changes upon brucia similar to those induced on strychnia.

The remaining properties of brucia are nearly the same as those of strychnia. Like that substance it dissolves readily in alcohol and volatile oils; but is insoluble in ether and in fixed oils.

From the experiments of Pelletier and Caventou, it appears that sulphate of brucia is composed as follows:

Equivalent number for.

Sulphuric acid....	8·84	 5
Brucia	91·16	...... 51·561
	100·00	

From this analysis it would appear that its equivalent number is 51·561.

Its action upon the animal œconomy is precisely the same as that of strychnia. But it has only $\frac{1}{12}$th of the force of that alkaline poison. It occasions tetanus, acting upon the nerves without affecting the intellectual faculties.[*]

V. PICROTOXIA.

History.

This is the substance to which the cocculus indicus, the fruit of the *menispermum cocculus* owes its deletereous qualities. Its nature and properties were investigated by Boullay in 1811.[†] He bestowed upon it the name of picrotoxin, from its bitter taste and its poisonous nature.[‡]

This name, for the reasons formerly stated, I have changed into *picrotoxia.*

How obtained.

Picrotoxia may be obtained by the following process: Boil the berries in a sufficient quantity of water. Filter the decoction, and add to it acetate of lead as long as any precipitate falls. Filter the liquid a second time, and evaporate it with caution to the consistence of an extract. Dissolve this extract in alcohol of the specific gravity 0·817. Evaporate this liquid to dryness. These alternate solutions and evaporations in water and alcohol must be repeated till the dry residue is completely soluble both in water and alcohol. It is now picrotoxia united with a yellow colouring matter. Agitate it with a small quantity of water. That liquid dissolves the colouring matter, which is very soluble and occasions the separation of a great number of small crystals which constitute picrotoxia nearly pure. Wash them with a little water and then with alcohol. Picrotoxia thus prepared possesses the following properties.

Properties.

Its colour is white. Its crystals have the figure of four-sided prisms. It is intensely bitter, and scarcely alters vegetable blues.

It is soluble in 25 times its weight of water and no reagent is capable of precipitating it from this solution. Alcohol of the specific gravity 0·810 dissolves one-third of its weight of it. Sulphuric ether of the specific gravity 0·7 dissolves two-fifths of its weight of it. It is insoluble in oils.

It combines with the different acids and neutralizes them, forming salts, the nature and properties of which have been but imperfectly ascertained.[§]

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[*] Pelletier and Caventou, Jour. de Pharmacie, v. 529.

[†] Ann. de Chim. lxxx. 209.

[‡] From πικρος, *bitter*, and τοξικον, *poison.*

[§] Boullay, Jour. de Pharmacie, iv. 367.

A solution of potash or soda in ten times its weight of water dissolves it. When triturated with potash it emits no smell of ammonia. It burns without melting. When swallowed it intoxicates and acts as a poison.

From the analysis of Boullay it appears that sulphate of picrotoxia is composed as follows:

Equivalent number for.

Sulphuric acid	9·99	5
Picrotoxia	90·01	45
	100·00[*]	

From this it appears that the equivalent number for the picrotoxia is 45.

VI. DELPHIA.

This alkaline substance was detected in July 1819 by MM. Lassaigne and Feneulle in the seeds of the *delphinium staphysagria* or *stavesacre*, a plant which grows wild in the southern provinces of France, and which in consequence of its acrid properties was formerly employed in medicine. The process by which delphia may be procured is the following.

The seeds were cleaned and reduced to a pulp by trituration in a mortar. This pulp was boiled for some time in water till every thing soluble was dissolved. The liquid after being filtered off was mixed with some pure magnesia and boiled for some time. A sediment was deposited which was separated by the filter and digested in boiling alcohol. The alcoholic solution being evaporated left the *delphia* in a state of tolerable purity.

Delphia, thus obtained, is a white powder having a crystalline texture while moist; but becoming opaque by exposure to the air. Its taste is very bitter and acrid; but it has no smell. On exposure to heat it melts and assumes the appearance of liquid wax; but, on cooling it becomes hard and brittle, similar to resin. When the heat is raised the delphia blackens, swells up, and emits a white smoke with a peculiar odour, which takes fire in the air. There remains a light charcoal which burns without leaving any residue.

Cold water has little action on delphia, yet it must dissolve a small portion of it as it acquires the acrid taste which distinguishes this alkali. Alcohol and sulphuric ether dissolve it with facility. The alcoholic solution gives a green colour to syrup of violets and restores the blue colour of litmus paper reddened by vinegar.

It unites with the different acids and neutralizes them, form-

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[*] Jour. de Pharmacie, v. 10.

ing salts which are very soluble in water, and which are distinguished by the acrid and bitter taste of delphia itself.

Besides these five alkaline bodies, it cannot be doubted that many others exist in the vegetable kingdom. Most of the bitter substances, and many of the vegetable poisons, are probably alkaline bodies.

SECT. II.

OF THE FIXED ALKALIES.

Origin.

The word ALKALI is of Arabian origin, and was introduced into chemistry after it had been applied to a plant which still retains the name of *kali*. When this plant is burnt, the ashes washed in water, and the water evaporated to dryness, a white substance remains, which was called *alkali*. According to Albertus Magnus, who uses the word, it signifies *fæx amaritudinis*, "the dregs of bitterness."* Alkali may be obtained from other substances besides kali. Chemists gradually discovered that bodies, differing from one another in several of their properties, had been confounded together under the same name. The word, in consequence, became general, and is now applied to all bodies which possess the following properties:

Properties.

1. A caustic taste.
2. Volatilized by heat.
3. Capable of combining with acids, and of destroying their acidity.
4. Soluble in water even when combined with carbonic acid.
5. Capable of converting vegetable blues to green.

AMMONIA, one of the alkalies described in the preceding section, because it is gaseous, is distinguished by the name of *volatile alkali*. POTASH, SODA, and LITHIA, because they are capable of bearing a red heat, are called *fixed alkalies*. The properties of these three substances constitute the subject of this section.

I. POTASH.

Black's discovery of the cause of causticity

When potash is obtained by the combustion of ferns or wood, as formerly described;† it is combined with carbonic

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* Theatrum Chemicum. ii. 470. I am indebted to my friend, the Rev. Mr. Holme, of St. Peter's College, Cambridge, for the following note, with which he was supplied by the Rev. Mr. Palmer, Professor of Arabic, at Cambridge, "From the Arabic root قلع (Kala,) to dress any thing by fire is derived the substantive قلي (Kilyon,) the ashes produced by burning the salicornia, or any other plants of the same nature. See Gotius' Arabic Lexicon at root preceding. Hence *Kali*, and with the article *Al-kali*."

† See vol. i. p. 326.

acid. When treated with quicklime it is deprived of its carbonic acid and obtained in a caustic state. It was long before chemists understood to what the changes produced upon it by lime were owing. According to some, it was deprived of a quantity of mucilage, in which it had formerly been enveloped; while, according to others, it was rendered more active by being more comminuted. At last, in 1756, Dr. Black proved, by the most ingenious and satisfactory analysis, that the *potash* which the world had considered as a simple substance, was really a compound, consisting of potash and carbonic acid; that lime deprived it of this acid; and that it became more active by becoming more simple.

While Dr. Black was thus occupied in Scotland, Mr. Meyer was employed in Germany in the same researches; from which, however, he drew very different conclusions. His Essays on lime appeared in 1764. Pouring into lime-water a solution of potash (*carbonate of potash*), he obtained a precipitate, which he found not to differ from lime-stone. The alkali had, therefore, deprived the lime of its causticity and its active properties; and these very properties it had itself acquired. From which he concluded, that the causticity of lime was owing to a particular acid with which it had combined during its calcination. The alkali deprived the lime of this acid, and therefore had a stronger affinity for it. To this acid he gave the name of *acidum pingue* or *causticum*. It was, according to him, a subtile elastic mixture, analogous to sulphur, approaching very nearly to the nature of fire, and actually composed of an acid principle and fire. It was expansible, compressible, volatile, astringent, capable of penetrating all vessels, and was the cause of causticity in lime, alkalies, and metals. This theory was exceedingly ingenious, and it was supported by a vast number of new and important facts. But notwithstanding the reputation and acknowledged genius and merit of its author, it never gained many followers; because the true theory of causticity, which had been already published by Dr. Black, soon became known on the continent; and though it met with some opposition at first, soon carried conviction into every unprejudiced mind. Mr. Jacquin, botanical professor at Vienna, published a Latin dissertation in defence of Dr. Black's doctrine in 1769. This work was opposed in 1770 by Crans, physician to the king of Prussia, who endeavoured to defend the hypothesis of Meyer, now dead, in a very elaborate treatise. The subject was resumed by M. Lavoisier in 1774 in his physical and chemical essays. He repeated the experiments of Dr. Black and his disciples, and confirmed them in every particular. Since that time the hypothesis of Meyer seems to have been abandoned by every one.

Properties of potash.

1. Pure potash was first obtained by Sir H. Davy. It may be obtained by exposing peroxide of potassium to a heat sufficiently strong to drive off the excess of oxygen. In that state it has a grey colour, and a vitreous fracture. It requires a strong heat to fuse it, and it dissolves in water without effervescence, but produces, by its solution, a great deal of heat.

Hydrate.

2. Potash, obtained by means of alcohol, is a combination of potash and water, or a hydrate of potash. If we suppose it a compound of 1 atom potash and 1 atom water, its constituents will be by weight

Potash	6	 100
Water	1·125	...... 18·75

Now Davy found that hydrate of potash, when heated with boracic acid, gave out between 17 and 18 per cent. of water. According to which experiment hydrate of potash is a compound of 100 potash + 21·21 water. This tallies with theory sufficiently well. For it is obvious that potash, prepared by alcohol, will often (always probably) be allowed to retain rather more water than is actually in chemical combination with the alkali. Its specific gravity is 1·7085.*

Solution in water.

3. The hydrate of potash has a very strong affinity for water. At the common temperature of the air, one part of water dissolves two parts of potash. The solution is transparent, very dense, and almost of the consistence of oil. It is in this state that potash is usually employed by chemists. When four parts of potash in powder and one of snow are mixed together, the mixture becomes liquid, and at the same time affords a quantity of caloric. This mixture was employed by Lowitz to produce artificial cold. When the aqueous solution of potash is evaporated to a proper consistency, the potash crystallizes. The shape of its crystals is very different, according to the way in which they have been produced. When allowed to form spontaneously, they are octahedrons in groupes, and contain 0·43 of water:† When formed by evaporation on the fire, they assume the figure of very thin transparent blades of extraordinary magnitude, which, by an assemblage of lines crossing each other in prodigious num-

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* Hassenfratz, Ann. de Chim. 28·11.

† According to Proust, the hydrate of potash contains only 0·30 of water. Jour. de Phys. lix. 266.

bers, present an aggregate of cells or cavities, commonly so very close, that the vessel may be inverted without losing one drop of the liquid which it contains.*

Action of supporters on potash.

II. The supporters of combustion have no action on potash at the common temperature of the atmosphere; but they act upon it in certain circumstances.

1. An additional dose of oxygen may be made to combine with potash, provided it contain no water; but the hydrate is incapable of forming this compound. The peroxide of potash may be obtained by burning potassium in oxygen gas. It is decomposed, and the oxygen driven off by dissolving it in water.

2. When potash is heated to redness and placed in contact with chlorine gas, the oxygen of the alkali is expelled and the chlorine takes its place.

3. The same substitution of iodine for oxygen takes place when the vapour of iodine is passed over hot potash.

Action of combustibles.

III. The simple combustibles produce very different effects on potash according to their peculiar nature.

1. Hydrogen gas has no sensible effect on it whatever. Neither does it combine, so far as is known, with carbon, boron, or silicon.

2. It would appear from the experiments of Sementini that phosphorus is capable of combining with potash and forming a phosphuret of potash. His method was to form a saturated solution of potash in alcohol, and to keep sticks of phosphorus in this liquid as long as they continued to dissolve. Brown shining scales were deposited which constituted the phosphuret of potash. According to Sementini they are soluble in water.†

Sulphuret of potash.

3. When three parts of sulphur and one of potash are triturated together in a glass mortar, the sulphur acquires a green colour, the mixture becomes hot, and exhales an alliaceous odour. It gradually attracts moisture from the air, and is totally soluble in water.‡ When two parts of potash and one of sulphur are heated in a crucible, they melt and combine, and form a sulphuret of potash. The potash of commerce may be also employed; for the carbonic acid separates in the form of a gas during the combination of the potash and sulphur. When the fusion is complete, the sulphuret is to be poured upon a marble slab; and as soon as it congeals, it must be broken in pieces, and set by in a well-corked phial.

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* Nicholson's Journal, i. 164.

† Annals of Philosophy, vii. 280.

‡ Fourcroy, ii. 203.

Sulphuret of potash, thus prepared, is of a brown colour, not unlike the liver of animals. Hence it was formerly called *hepar sulphuris*, "liver of sulphur;" but when exposed to the air, it soon becomes green, and even white. It is hard, brittle, and has a glassy fracture. Its taste is acrid, caustic, and bitter, and it leaves a brown stain upon the skin. It has no other smell than that of sublimed sulphur. When exposed to a violent heat, the sulphur sublimes, and the potash remains in a state of purity. This sulphuret converts vegetable blues to green, and soon destroys them. When heated with charcoal, it dissolves and combines with it.*

Hydroguretted sulphuret.

When sulphuret of potash is exposed to the air, or when it is moistened with water, its properties very soon change. It acquires a green colour, and exhales the odour of sulphuretted hydrogen gas. This change is owing to the formation of a quantity of sulphuretted hydrogen, in consequence of the decomposition of the water. This new-formed substance combines with the sulphuret, and converts it into hydroguretted sulphuret of potash, which is soluble in water, and has a brownish-green colour. It may be formed also by boiling in water two parts of potash and one part of sulphur. Sulphuret of potash produces no change upon air, but hydroguretted sulphuret gradually absorbs oxygen. When inclosed in a vessel with a quantity of air, it soon absorbs all the oxygen of that portion, and leaves nothing but azotic gas. This fact, which was first observed by Scheele, induced him to use hydroguretted sulphuret to measure the quantity of oxygen contained in any given portion of atmospheric air. Hydroguretted sulphuret is capable of oxidizing and dissolving almost all the metals. We are indebted to Mr. Berthollet for the first accurate account of the difference between these two substances.†

Sulphuret of potash has not hitherto been analyzed. It ought from theory to be a compound of 3 parts by weight of potash and 1 part of sulphur; or of an atom of potash and an atom of sulphur.

Action on metals.

4. Potash does not combine with any of the metals; but some of the metals which have a strong affinity for oxygen, when put into a solution of potash in water, especially if heat be applied, are gradually oxidized. This is the case with molybdenum, zinc, and iron. Tin also is oxidized in a very

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* Fourcroy, ii. 203.

† Ann. de Chim. xxv. 233. See also Proust, Jour. de Phys. lix. 265.

small proportion; and this seems also to be the case with manganese.

And their oxides.

It is capable of dissolving a considerable number of the metallic oxides; and in some cases it deprives them of a dose of their oxygen. Thus when poured upon the red oxide of iron, it soon converts it into the black. The cause of this change is unknown. It has been ascertained, that the oxides of the following metals are soluble in potash:

Lead,*
Tin,
Nickel,
Arsenic,
Cobalt,
Manganese,
Zinc,
Antimony,
Tellurium,
Tungsten,
Molybdenum.

But the nature of these solutions has not hitherto been examined with any degree of attention; though the subject is remarkably curious, and promises to throw light both upon the nature of alkalies and metals.

II. SODA.

Soda procured by the process formerly described† is in the state of a *hydrate*. Pure soda was first obtained by Sir H. Davy by burning sodium, by means of a strong heat in a quantity of air just sufficient to convert it into soda.

Properties.

Pure soda has a grey colour, is a non-conductor of electricity, has a vitreous fracture, and requires a strong red heat to melt it. When a little water is added the soda combines with it rapidly, evolving considerable heat; it becomes at the same time white, crystallized in its texture, and much more fusible than formerly. In this state it is a hydrate of soda, which, when pure, is a compound of 1 atom soda and 1 atom water, or is composed by weight of

Soda	4	100
Water	1·125	28·1

D'Arcet's analysis gives us the hydrate of soda composed of 100 soda + 38·8 water,‡ while that of Berard gives its composition 100 soda + 23·2 water.§ Now the mean of these two gives 100 soda + 31 water, which differs as little as can well be expected from the theoretic number, when we consider

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* Bergman, iii. 456. Proust, Jour. de Phys. lvi. 207.

† Vol. i. p. 336.

‡ Ann. de Chim. lxviii. 175, and lxxi. 20.

§ Ann. de Chim. lxxii. 96.

the strong tendency that soda has to unite with more water. It dissolves very readily in water and may be obtained in crystals by evaporating the aqueous solution. Its specific gravity is 1·336.*

IV. The action of the supporters of combustion, and of the simple combustibles on soda, is so nearly the same as on potash, that a particular description of the phenomena does not seem necessary.

How distinguished from potash.

V. It is easy to distinguish potash from soda by the following properties. 1. When potash is exposed to the air it speedily absorbs moisture and remains in the state of an oily looking liquid; but soda, though at first it becomes doughy, soon dries again and remains in the state of a white dry powder. 2. When potash is neutralized with sulphuric acid it forms a salt, which crystallizes in small irregular crystals which have more or less the shape of six-sided prisms terminated by six-sided pyramids, and requiring 16 times its weight of water to dissolve it. But soda neutralized by the same acid forms a salt, which dissolves in less than its weight of boiling water, and crystallizes on cooling in large transparent, channelled, six-sided prisms, which, when exposed to the air, speedily fall down in the state of a white powder. 3. When sulphate of potash is dissolved in water, if a little tartaric acid be dropt into the solution, a number of minute crystals are deposited. A yellow precipitate appears when nitro-muriate of platinum is dropped into the same solution. But sulphate of soda is neither precipitated by tartaric acid, nor nitro-muriate of platinum.

III. LITHIA.

This alkali has been recently discovered in the mineral called *petalite*, by Mr. Arvedson. Its properties, as far as they have been determined, have been already described in vol. i. p. 343 of this work.

It has the same caustic taste, and the same action on vegetable blues as potash or soda. But it differs from these alkalies in various particulars. A concentrated solution of it in water is precipitated *white* by an alkaline carbonate. It is not precipitated from water or any saline solution by tartaric acid, or muriate of platinum. It does not deliquesce when exposed to the air; but absorbs carbonic acid. It is not so

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* Hassenfratz, Ann. de Chim. xxviii. 11.

easily volatilized as potash and soda, being capable of bearing a white heat for a considerable time without any sensible diminution of its weight. Alcohol has the property of precipitating it from water in the course of a few hours, in the state of a fine powder. The nitrate and muriate of lithia are exceedingly deliquescent salts.

The weights of an integrant particle of each of these three alkalies are to each other, as the following numbers :

Potash	6
Soda	4
Lithia	2·25

SECT. III.

OF THE ALKALINE EARTHS.

THE word earth, in common language, has two meanings; it sometimes signifies the *globe*, which we inhabit, and sometimes the *mould* on which vegetables grow. Chemists have examined this mould, and have found that it consists of a variety of substances mixed together without order or regularity. The greatest part of it, however, as well as of the stones which form apparently so large a proportion of the globe, consists of a small number of bodies, which have a variety of common properties. These bodies chemists formerly classed together, and denominated *earths.* Though we now know that all these substances are in reality *metallic oxides*, yet the term *earth* having been long generally used both by chemists and mineralogists, could not easily be eradicated. I have thought it better to retain it, though it is obvious that no definition could be given of them which would not apply equally well to other metallic oxides.

The earths have been divided into two classes, namely, *alkaline earths* and *earths proper.* The first have the property of giving a green colour to vegetable blues, and of neutralizing acids; the second do not alter vegetable blues, and are incapable of neutralizing acids.

The alkaline earths are four in number ; namely,

Lime,
Barytes,
Strontian,
Magnesia.

We shall describe each of them in the order in which they have been named.

Subdivis. I. Chap. II.

I. LIME.

When lime is obtained by the process formerly described* it is a white powder, having a caustic taste, and capable of converting vegetable blues into green, and finally into yellow, when it acts upon them in solution in water.

Fusion of lime.

2. It cannot be fused by the most violent heat of our furnaces. But Dr. Clarke has succeeded in fusing it by means of a blow pipe, consisting of a jet of two volumes hydrogen, and one volume oxygen gases, issuing with violence from the point of a capillary tube. It is converted into a brilliant limpid glass, and during the fusion a beautiful lambent flame of an amethystine hue makes its appearance.†

Slacking of lime.

3. If water be poured on newly burnt lime, it swells and falls to pieces, and is soon reduced to a very fine powder. In the mean time, so much heat is produced, that part of the water flies off in vapour. If the quantity of lime slacked (as this process is termed) be great, the heat produced is sufficient to set fire to combustibles. In this manner, vessels loaded with lime have sometimes been burnt. When great quantities of lime are slacked in a dark place, not only heat but light also is emitted, as Mr. Pelletier has observed.‡ When slacked lime is weighed, it is found to be heavier than it was before. This additional weight is owing to the combination of part of the water with the lime; which water may be separated again by the application of a red heat; and by this process the lime becomes just what it was before being slacked.§ Hence the reason of the heat evolved during the slacking of lime. Part of the water combines with the lime, and thus becomes solid; of course it parts with its caloric of fluidity, and probably also with a considerable quantity of caloric which exists in water even when in the state of ice: for when two parts of lime and one part of ice (each at 32°) are mixed, they combine rapidly, and their temperature is elevated to 212°. The elevation of temperature during the slacking of barytes and strontian is owing to the same cause.

Hydrate of lime.

Slacked lime or *hydrate of lime* is no doubt a compound of 1 atom lime + 1 atom water, or it is composed by weight of

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* See vol. i p. 347.

† Journal of the Royal Institution, ii. 113.

‡ Jour. de Phys. i. 22.

§ Dr. Black.

Lime	3·625	100
Water	1·125	31·03

Now Mr. Dalton* found slacked lime well dried in a moderate heat composed of

Lime	100
Water	33·3

The result of Lavoisier's experiments† gave

Lime	100
Water	28·7

Now the mean of these two experiments give us the composition of hydrate of lime as follows:

Lime	100
Water	31·03

which is exactly the theoretical result.

Gay-Lussac has lately hit upon a very ingenious method of crystallizing lime. He dissolves it in water, and places the lime water formed in an open vessel under the exhausted receiver of an air pump, along with a quantity of concentrated sulphuric acid in another open vessel. When the acid has become too weak in consequence of the evaporation of the lime water it is withdrawn, and new concentrated acid substituted in its place. By degrees the lime is deposited in small crystals, which exhibit the form of fragments of six-sided prisms.‡

Solubility in water.

By my trials 758 grains of cold water dissolve 1 grain of lime. According to Mr. Dalton who has examined this subject with attention, cold water dissolves more lime than hot water. The following table shows the solubility of lime and its hydrate in water of different temperatures, according to his experiments.§

1 Part of water at	Takes up of lime	Takes up of dry hydrate
60°	$\frac{1}{778}$	$\frac{1}{384}$
130	$\frac{1}{972}$	$\frac{1}{729}$
212	$\frac{1}{1270}$	$\frac{1}{952}$

Lime water, as this solution is called, is limpid, has an acrid taste, and changes vegetable blue colours to green. It is usually

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* New System of Chemical Philosophy, i. 87.

† Lavoisier's Essays, translated by Henry, p. 280.

‡ Ann. de Chim. et Phys. i. 334.

§ New System of Chemical Philosophy, ii. 510.

formed by throwing a quantity of lime in powder into pure water, allowing it to remain for some time in a close vessel, and then decanting the transparent solution from the undissolved lime. When lime-water is exposed to the air, a stony crust soon forms on its surface composed of carbonate of lime; when this crust is broken it falls to the bottom, and another succeeds it; and in this manner the whole of the lime is soon precipitated, by absorbing carbonic acid from the air.

The smell perceived during the slacking of lime is owing to a part of that earth being elevated along with the vapour of the water; as evidently appears from this circumstance, that vegetable blues exposed to this vapour are converted into green.

Difference between limestone and lime.

Limestone and chalk, though they are capable of being converted into lime by *burning*, possess hardly any of the properties of that active substance. They are tasteless, scarcely soluble in water, and do not perceptibly act on animal bodies. Now, to what are the new properties of lime owing? What alteration does it undergo in the fire?

It had been long known, that limestone loses a good deal of weight by being burned or *calcined*. It was natural to suppose, therefore, that something is separated from it during calcination. Accordingly, Van Helmont, Ludovicus, and Macquer, made experiments in succession, in order to discover what that *something* is; and they concluded from them that it is *pure water*, which the lime recovers again when exposed to the atmosphere. As the new properties of lime could hardly be ascribed to this loss, but to some other cause, Stahl's opinion, like all the other chemical theories of that wonderful man, was generally acceded to. He supposed that the new properties which lime acquired by calcination are owing entirely to the more minute division of its particles by the action of the fire. Boyle indeed had endeavoured to prove that these properties are owing to the *fixation of fire* in the lime; a theory which was embraced by Newton and illustrated by Hales, and which Meyer new modelled, and explained with so much ingenuity and acuteness as to draw the attention of the most distinguished chemists. But while Meyer was thus employed in Germany, Dr. Black of Edinburgh published, in 1756, those celebrated experiments which form so brilliant an era in the history of chemistry.

Discovered by Dr. Black.

He first ascertained, that the quantity of water separated from limestone during its calcination is not nearly equal to the weight which it lost. He concluded in consequence, that it must have lost something else than mere water. What this could be, he was at first at a loss to conceive; but recollecting that Dr. Hales had proved that limestone, during its solution in acids, emits a great quantity of *air*, he conjectured that *this* might probably be what is lost during calcination. He calcined it accordingly, and applied a pneumatic apparatus to receive the product. He found his conjecture verified; and that the *air* and the *water* which separated from the lime were together precisely equal to the loss of weight which it had sustained. Lime therefore owes its new properties to the loss of *air;* and limestone differs from lime merely in being combined with a certain quantity of *air:* for he found that, by restoring again the same quantity of *air* to lime, it was converted into lime-stone. This air, because it existed in lime in a fixed state, he called *fixed air*. It was afterwards examined by Dr. Priestley and other philosophers; found to possess peculiar properties, and to be that species of gas now known by the name of *carbonic acid gas.* Lime then is the simple substance, and limestone is composed of carbonic acid and lime. Heat separates the carbonic acid, and leaves the lime in a state of purity.

4. When lime is exposed to the open air, it gradually attracts moisture, and falls to powder; after which it soon becomes saturated with carbonic acid, and is again converted into carbonate of lime or unburnt limestone.

Action of supporters.

II. Of the supporters of combustion, the only one which decomposes lime is chlorine. When this gas is passed over red-hot lime the oxygen is disengaged, and the chlorine combines with the calcium. According to the experiments of Gay-Lussac, iodine combines with lime without decomposing it, and forms an iodide of lime.

III. The action of the simple combustibles on lime has been but imperfectly examined.

1. Hydrogen, carbon, boron, and silicon, so far as is known, have no action on lime.

Phosphuret.

2. Phosphuret of lime may be formed by the following process: Put into the bottom of a glass tube, close at one end, 1 part of phosphorus; and, holding the tube horizontally, introduce 5 parts of lime in small lumps, so that they shall be about two inches above the phosphorus. Then place the tube horizontally among burning coals, so that the part of it which contains the lime may be made red-hot, while the bottom of the tube containing the phosphorus remains cold. When the lime becomes red-hot, raise the tube, and draw it along the coals

till that part of it which contains the phosphorus is exposed to a red heat. The phosphorus is immediately volatilized, and passing through the hot lime combines with it. During the combination the mass becomes of a glowing red heat, and a quantity of phosphuretted hydrogen gas is emitted, which takes fire when it comes into the air. This curious process was contrived by Mr. Tennant, to whom we are indebted for the discovery of the earthy phosphurets.

Phosphuret of lime has a deep brown colour, and is moulded into the shape of the tube. It falls to pieces in the air. It is insoluble in water; but it has the property of decomposing that liquid. Phosphuretted hydrogen gas is emitted, which takes fire as soon as it comes to the surface of the water.

No analysis of phosphuret of lime has been hitherto attempted. But there can be little doubt that it is a compound of 1 atom lime and 1 atom phosphorus, or that it consists by weight of

Lime	3·625	100
Phosphorus	1·5	41·38

Sulphuret.

3. Sulphuret of lime may be formed by mixing its two component parts, reduced to a powder, and heating them in a crucible. They undergo a commencement of fusion, and form an acrid reddish mass. When it is exposed to the air, or moistened with water, its colour becomes greenish-yellow, sulphuretted hydrogen is formed, and the sulphuret is converted into a hydroguretted sulphuret, which exhales a very fetid odour of sulphuretted hydrogen gas. This hydroguretted sulphuret may be formed also by boiling a mixture of lime and sulphur in about ten times its weight of water, or by sprinkling quicklime with sulphur, and then moistening it: the heat occasioned by the slacking of the lime is sufficient to form the combination. When this hydroguretted sulphuret is exposed to the air, it imbibes oxygen; which combines at first with the hydrogen, and afterwards with the sulphur, and converts the compound into hyposulphite of lime. When the solution of hydroguretted sulphuret of lime is kept in a close vessel, the sulphur gradually precipitates, and hydro-sulphuret of lime remains in solution.

The hydroguretted sulphuret of lime has the property of dissolving charcoal by the assistance of heat, and of retaining it in solution.* It acts very powerfully upon metals and metallic oxides.

The sulphuret of lime has not hitherto been analysed, but there can be little doubt that it is a compound of 1 atom lime + 1 atom sulphur, or by weight of

Lime	3·625	100
Sulphur	2·000	55·17

Action of metals,

4. Lime facilitates the oxidizement of several of the metals, and it combines with several of the metallic oxides, and forms salts which have not hitherto been examined, if we except the compounds which it forms with the oxides of mercury and lead, which have been described by Berthollet.

And their oxides.

The red oxide of mercury, boiled with lime-water, is partly dissolved, and the solution yields by evaporation small transparent yellow crystals.† This compound has been called by some *mercuriate of lime.*

Lime water also dissolves the red oxide of lead, and (still better) litharge. This solution, evaporated in a retort, gives very small transparent crystals, forming prismatic colours, and not more soluble in water than lime. It is decomposed by all the alkaline sulphates, and by sulphuretted hydrogen gas. The sulphuric and muriatic acids precipitate the lead. This compound blackens wool, the nails, the hair, white of eggs; but it does not affect the colour of silk, the skin, the yolk of an egg, nor animal oil. It is the lead which is precipitated on these coloured substances in the state of oxide; for all acids can dissolve it. The simple mixture of lime and oxide of lead blackens these substances, a proof that the salt is easily formed.‡

Mortar.

IV. One of the most important uses of lime is the formation of *mortar* as a cement in building. Mortar is composed of quicklime and sand reduced to a paste with water. When dry it becomes as hard as stone, and as durable; and adhering very strongly to the surfaces of the stones which it is employed to cement, the whole wall becomes in fact nothing else than one single stone. But this effect is produced very imperfectly unless the mortar be very well prepared.

The lime ought to be pure, completely free from carbonic acid, and in the state of a very fine powder: the sand should be free from clay, and partly in the state of fine sand, partly in that of gravel: the water should be pure; and if previously

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* Fourcroy, ii. 174.

† Berthollet, Ann. de Chim. i. 61.

‡ Ibid. 52.

saturated with lime, so much the better. The best proportions, according to the experiments of Dr. Higgins, are 3 parts of fine sand, 4 parts of coarser sand, 1 part of quicklime recently slacked, and as little water as possible.

The stony consistence which mortar acquires is owing, partly to the absorption of carbonic acid, but principally to the combination of part of the water with the lime. This last circumstance is the reason, that if to common mortar one fourth part of lime, reduced to powder without being slacked, be added, the mortar when dry acquires much greater solidity than it otherwise would do. This was first proposed by Loriot;[*] and a number of experiments were afterwards made by Morveau.[†] The proportions which this philosopher found to answer best are the following:

Fine sand	0·3
Cement of well baked bricks	0·3
Slacked lime	0·2
Unslacked lime	0·2
	1·0

The same advantages may be attained by using as little water as possible in slacking the lime. This was first pointed out by La Faye.[‡]

Higgins found that the addition of burnt bones improved mortar by giving it tenacity, and rendering it less apt to crack in drying; but they ought never to exceed one fourth of the lime employed.

When a little clay is added to mortar, it acquires the important property of hardening under water; so that it may be employed in constructing those edifices which are constantly exposed to the action of water. Limestone is found not unfrequently mixed with clay: and in that case it becomes brown by calcination, instead of white. These native limestones are employed for making *water mortar;* but good water mortar may be made by the following process, first proposed by Morveau: Mix together 4 parts of blue clay, 6 parts of black oxide of manganese, and 90 parts of limestone, all in powder. Calcine this mixture to expel the carbonic acid, mix it with 60 parts of sand, and form it into mortar with a sufficient quantity of water.[§]

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[*] Jour. de Phys. iii. 231.

[†] Ibid. vi. 311.

[‡] Ibid. ix. 437.

[§] Ann. de Chim. xxxvii. 259.

The best mortar for resisting water is made by mixing with lime puzzolano, a volcanic sand brought from Italy. Morveau informs us that *basaltes*, which is very common in this country, may be substituted for puzzolano. It must be heated in a furnace, thrown while red-hot into water, and then passed through a sieve to reduce it to the proper size.*

II. BARYTES.

Barytes when prepared according to the process described in a preceding part of this work,† is a greyish porous body which may be easily reduced to powder. Its taste is more acrid than that of lime. It is poisonous, converts vegetable blues to green, and is more soluble in water than lime.

When exposed to the air, it immediately attracts moisture; in consequence of which it swells, heat is evolved, and the barytes falls to a white powder, just as happens to quicklime when water is sprinkled on it.‡ After the barytes is thus *slacked*, it gradually attracts carbonic acid, and loses its acrid properties, its weight being increased 0·22.§ It cannot therefore be kept pure except in close vessels.

Action of water.

2. When a little water is poured upon barytes, it is slacked like quicklime, but more rapidly, and with the evolution of more heat. The mass becomes white, and swells considerably. If the quantity of water be sufficient to dilute it completely, the barytes crystallizes in cooling, and assumes the appearance of a stone composed of needle-form crystals; but when exposed to the air, it gradually attracts carbonic acid, and falls to powder.||

Water is capable of dissolving 0·05 parts of its weight of barytes. This solution, which is known by the name of *barytes water*, is limpid and colourless, has an acrid taste, and converts vegetable blues first to a green and then destroys them. When exposed to the air, its surface is soon covered with a stony crust, consisting of the barytes combined with carbonic acid.

Boiling water dissolves more than half its weight of barytes. As the solution cools, the barytes is deposited in crystals; the shape of which varies according to the rapidity with which they have been formed. When most regular, they are flat hexagonal prisms, having two broad sides, with two intervening

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* Ann. de Chim. xxxvii. 262.

† Vol. i. p. 352.

‡ Fourcroy and Vauquelin, Ann. de Chim. ii. 59.

§ Mem. de l'Instit. ii. 59.

|| Fourcroy, ii. 193.

narrow ones, and terminated at each end by a four-sided pyramid, which in some instances constitutes the larger part of the crystal. When formed slowly, they are distinct and large; but when the water is saturated with barytes, they are deposited rapidly, and are generally more slender and delicate. Then, too, they are attached to one another in such a manner as to assume a beautiful foliaceous appearance, not unlike the leaf of a fern.*

These crystals are transparent and colourless, and appear to be composed of about 53 parts of water and 47 of barytes. When exposed to the heat of boiling water, they undergo the *watery fusion;* that is to say, the water which they contain becomes sufficient to keep the barytes in solution. A stronger heat drives off part of the water but not the whole. When exposed to the air, they attract carbonic acid, and crumble into dust. They are soluble in 17½ parts of water at the temperature of 60°; but boiling water dissolves any quantity whatever: the reason of which is evident; at that temperature their own water of crystallization is sufficient to keep them in solution.†

It was observed by Bucholz and Gehlen that when the crystals of barytes are exposed to heat, they readily melt in their water of crystallization. As this water evaporates the barytes is reduced to a dry mass. This mass again melts when heated to redness and flows like an oil. But barytes procured from the nitrate of that earth by heat is infusible in the strongest heat that can be raised in our furnaces.‡ The reason of this difference is that the barytes obtained by heat from the crystals is in the state of *hydrate*, while the earth from the nitrate is free from water. From the experiments of Dalton, it appears, that water combines in at least 3 proportions with barytes, and forms 3 solid hydrates.

Hydrates.

	Barytes.		Water.
1st composed of	1 atom	+	1 atom.
2d	1	+	5
3d	1	+	20

The first is formed by exposing crystallized barytes to a strong red heat; the second by reducing the crystals to a dry powder by heat; and the third consists of crystallized barytes.§ The first hydrate is composed of

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* Hope, Edin. Trans. iv. 36.

† Ibid.

‡ Gehlen's Journal für die Chemie, Physik und Mineralogie, iv. 258.

§ New System of Chemical Philosophy, ii. 522.

Barytes	9·75	100
Water	1·125	11·53

The second hydrate is composed of

Barytes	9·75	100
Water	5·625	57·69

The third hydrate is composed of

Barytes	9·75	100
Water	22·50	230·76

Action of supporters.

II. Barytes, according to the experiments of Gay-Lussac and Thenard, is capable of uniting with an additional dose of oxygen.

2. When chlorine is passed over it at a red heat, the oxygen of the barytes is expelled and chloride of barium formed.

3. Iodine combines with it without expelling the oxygen, and forms iodide of barium.

III. Of the simple combustibles, hydrogen, carbon, boron, and silicon, so far as is known, have no action on it.

Phosphuret.

2. Phosphuret of barytes may be formed by putting phosphorus and barytes into a glass tube close at one end, and heating the tube upon burning coals, as in making phosphuret of lime. The combination takes place very rapidly. This phosphuret is of a dark brown colour, very brilliant, and very fusible. When moistened, it exhales the odour of phosphuretted hydrogen gas. When thrown into water, it is gradually decomposed, phosphuretted hydrogen gas is emitted, which takes fire when it comes to the surface of the water, and the phosphorus is gradually converted into phosphoric acid.[*] This phosphuret has not been analysed; but it is probably composed of 1 atom barytes + 1 atom phosphorus, or by weight of

Barytes	9·75	100
Phosphorus	1·5	15·78

Sulphuret.

3. Sulphuret of barytes may be formed by mixing its two ingredients together and heating them in a crucible. The mixture melts at a red heat, and when cold forms a mass of a reddish-yellow colour, without any smell, which is *sulphuret of barytes.* This sulphuret decomposes water with great rapidity; sulphuretted hydrogen is formed, which, combining with the

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[*] Fourcroy, ii. 191.

sulphuret, converts it into a hydroguretted sulphuret. This change takes place whenever the sulphuret is moistened with water, or even exposed to the atmosphere. When boiling water is poured upon sulphuret of barytes, a great quantity of sulphuretted hydrogen is formed almost instantaneously, which combines with the water, and occasions the solution of the sulphuret. When the solution cools, a great number of brilliant white crystals are deposited, sometimes in the form of needles, sometimes in six-sided prisms, and sometimes in hexagonal plates. These crystals are composed of sulphuretted hydrogen and barytes, and have been called by Berthollet, to whom we are indebted for the first accurate account of them, *hydrosulphuret of barytes.* The liquid which has deposited the hydrosulphuret is of a yellow colour, and holds in solution a *hydroguretted sulphuret of barytes.*[*] No doubt this sulphuret is a compound of 1 atom barytes + 1 atom sulphur, or by weight of

Barytes	9·75	100
Sulphur	2·00	20·51

Action of metals and their oxides.

4. Barytes has no action on metals; but it is capable of combining with several of the metallic oxides, and forming with them compounds which have not hitherto been much examined. For instance, if it be poured into a solution of silver or lead in nitric acid, it precipitates the first brown, and the second white; but if an excess of barytes water be added, the precipitates are redissolved.[†]

IV. We are indebted to Bucholz for a set of experiments on the action of barytes on the other earthy bodies. Lime does not seem to unite with it. When equal quantities of the two earths are heated in a crucible, a mass is obtained, having some cohesion, but soluble in water.[‡] The phenomena were nearly the same when barytes and magnesia were heated together. When the resulting mass was treated with water, the barytes dissolved, but took up more of the magnesia.[§]

III. STRONTIAN.

Strontian prepared by the process described in a preceding

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[*] Berthollet, Ann. de Chim. xxv. 233.

[†] Fourcroy and Vauquelin, Mem. de l'Instit. ii. 61.

[‡] Bucholz's Beitrage, iii. 59. He seems not to have used pure lime, but a submuriate.

[§] Bucholz's Beitrage, iii. p. 56.

part of this work[*] is a porous mass of a greyish white colour. It has an acrid taste and converts vegetable blues to green.

Action of water.

When water is sprinkled on strontian it is slacked, becomes hot, and falls to powder exactly like barytes; but it is not so soluble in water as that earth. One hundred and sixty two parts of water, at the temperature of 60°, dissolve nearly one part of strontian. The solution, known by the name of *strontian water*, is clear and transparent, and converts vegetable blues to a green. Hot water dissolves it in much larger quantities; and as it cools, the strontian is deposited in colourless transparent crystals. These are in the form of thin quadrangular plates, generally parallelograms, the largest of which seldom exceeds one-fourth of an inch in length. Sometimes their edges are plain, but they oftener consist of two facets, meeting together, and forming an angle like the roof of a house. These crystals generally adhere to each other in such a manner as to form a thin plate of an inch or more in length and half an inch in breadth. Sometimes they assume a cubic form. They contain about 68 parts in 100 of water. They are soluble in 51·4 parts of water at the temperature of 60°. Boiling water dissolves nearly half its weight of them. When exposed to the air, they lose their water, attract carbonic acid, and fall into powder.[†] Their specific gravity is 1·46.[‡]

It appears from the experiments of Bucholz, that strontian obtained by heating these crystals has the property of fusing at a red heat, while strontian from the nitrate is destitute of that property.[§] Hence it is obvious that the first is a *hydrate of strontian*. It is, no doubt, composed of 1 atom strontian + 1 atom water, or by weight of

Strontian . .	6·500	100
Water	1·125	17·3

The crystals of strontian appear from Dr. Hope's analysis above stated, to be composed of 1 atom strontian + 12 atoms water, or by weight of

Strontian . .	6·5	100
Water	13·5	207·69

Tinges flame red.

Strontian has the property of tinging flame of a beautiful red, or rather purple colour; a property discovered by Dr. Ash

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[*] See vol. i. p. 360.

[†] Hope, Edin. Trans. iv. 44.

[‡] Hassenfratz, Ann. de Chim. xxviii. 11.

[§] Gehlen's Journal für de Chemie, Physick, und Mineralogie, iv. 604.

in 1787. The experiment may be made by putting a little of the salt composed of nitric acid and strontian into the wick of a lighted candle;* or by setting fire to alcohol, holding muriate of strontian in solution. In both cases the flame is of a lively purple. In this respect it differs from barytes, which when tried in the same way is found to communicate a bluish yellow tinge to the flame.†

II. Of the simple supporters oxygen does not appear to have any action on strontian. Chlorine decomposes it at a red heat and forms a chloride of strontium. Iodine combines with strontian and forms an iodide of strontian.

III. Of the simple combustibles, hydrogen, carbon, boron, and silicon, have no action on strontian, so far as is known.

2. Phosphuret of strontian may be prepared in the same way as the phosphuret of barytes. Its properties are similar.

Sulphuret.

3. The sulphuret of strontian may be made by fusing the two ingredients in a crucible. It is soluble in water by means of sulphuretted hydrogen, which is evolved. When the solution is evaporated, hydrosulphuret of strontian is obtained in crystals, and hydroguretted sulphuret remains in solution. These three compounds resemble almost exactly the sulphuret, hydrosulphuret, and hydroguretted sulphuret of barytes; and do not therefore require a particular description.

4. Strontian has no action upon metals; but it combines with several of their oxides, and forms compounds which have not hitherto been examined.

IV. Barytes and strontian resemble each other in their properties as closely as potash and soda: hence, like these two alkalies, they were for some time confounded. It is in their combination with acids that the most striking differences between these two earths are to be observed.

IV. MAGNESIA.

Magnesia obtained by the process formerly described‡ is a soft white elastic powder, with very little taste, and destitute of smell. It is insoluble in water, but converts vegetable blues to green.

Properties.

It is not melted by the strongest heat which it has been possible to apply; but Mr. Darcet observed that, in a very high temperature, it became somewhat agglutinated. When formed

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* Vauquelin, Jour. de Min. An. vi. 10.

† Pelletier, Ann. de Chim. xxi. 137.

‡ See vol. i. p. 364.

into a cake with water, and then exposed to a violent heat, the water is gradually driven off, and the magnesia contracts in its dimensions; at the same time, as Mr. Tingry informs us, it acquires the property of shining in the dark when rubbed upon a hot iron plate. Dr. Clarke by a stream of oxygen and hydrogen gases, fused it with great difficulty into a white enamel.

2. Though insoluble in water it forms a dry hydrate which is composed of 1 atom magnesia + 1 atom water, or by weight of

Magnesia	2·5	100
Water	1·125	45

Magnesia has never yet been obtained in a crystallized form.

When exposed to the air, it attracts carbonic acid gas and water; but exceedingly slowly. Butini left a quantity of it for two years in a porcelain cup merely covered with paper; its weight was only increased $\frac{1}{144}$ part.

Action of supporters,

II. Of the simple supporters, oxygen has no action on it. Chlorine decomposes it at a red heat and forms chloride of magnesium; iodine combines with it and forms iodide of magnesia.

Of simple combustibles.

III. The only one of the simple combustibles with which it can be united is sulphur. No person has hitherto succeeded in forming a phosphuret of magnesia. In this respect it differs from the other three alkaline earths.

The sulphuret of magnesia may be formed by exposing a mixture of two parts of magnesia and one part of sulphur to a gentle heat in a crucible. The result is a yellow powder, slightly agglutinated, which emits very little sulphuretted hydrogen gas when thrown into water. A moderate heat is sufficient to drive off the sulphur.*

Metals.

Magnesia has no action upon the metals; nor does it combine, as far as is known at present, with the metallic oxides, unless some intermediate substance be present.

Union with lime and strontian.

IV. Mr. Kirwan has shown that there is but little affinity between strontian and magnesia. They do not melt when exposed to a strong heat, at least when the strontian exceeds or equals the magnesia.†

Equal parts of lime and magnesia, mixed together, and exposed by Lavoisier to a very violent heat, did not melt; neither did they melt when Mr. Kirwan placed them in the temperature of 150° Wedgewood. The following table, drawn up by

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* Fourcroy, ii. 165.

† Irish Trans. v. 246, 247.

Mr. Kirwan from his own experiments, shows the effect of heat on these two earths mixed together in different proportions.

Proportions.	Heat.	Effect.
80 Lime 20 Mag.	150° Wedg.	Went through the crucible.
75 Lime 25 Mag.	160	Went through the crucible.
66 Lime 33 Mag.		Went through the crucible.
20 Lime 80 Mag.	165	Did not melt.
33 Lime 66 Mag.	138	Did not melt.
30 Lime 10 Mag.	156	Melted into a fine greenish yellow glass; but the crucible was corroded throughout.

Magnesia is used only in medicine. It is administered internally to remove acidity in the stomach.

SECT. IV.

OF THE EARTHS PROPER.

The earths proper are distinguished from the alkaline earths by being insoluble in water, and by producing no change upon vegetable blue colours. They were formerly reckoned six. But *silica*, which was classed among them, has been recognised as possessed of *acid* properties. We must in consequence reserve it for the next chapter. The earths proper then are the five following.

- Yttria,
- Glucina,
- Alumina,
- Zirconia,
- Thorina.

We shall describe them in the order in which they have been named.

1. YTTRIA.

Properties.

Yttria, obtained by the process formerly described,* is a white tasteless powder insoluble in water, alcohol, and caustic alkalies.

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* See vol. i. p. 368.

Book II. Division I.

Sulphuric, nitric, muriatic, and acetic acids, dissolve it, forming crystallizable salts, which have a sweet astringent taste, are soluble in water, and redden vegetable blues.

Phosphoric, carbonic, oxalic, tartaric, and citric acids, form with it insoluble salts which do not act on vegetable blues.

It may be precipitated from all its soluble salts by phosphate of soda, carbonate of soda, oxalate of ammonia, tartrate of potash.

Ferrochyazate of potash likewise throws it down. Carbonate of yttria loses 32 per cent. when calcined.

Yttria is precipitated by the alkalies and alkaline earths; but it precipitates glucina, alumina, and zirconia.*

II. GLUCINA.

Properties.

Glucina, obtained by the process formerly described,† is a white and very light powder, destitute of taste and smell, insoluble in water and alcohol; but soluble in caustic alkalies. It dissolves likewise in carbonate of ammonia, in which respect it agrees with yttria; but its solubility in that liquid is five times greater than that of yttria.

It is not precipitated by oxalate of ammonia nor tartrate of potash. But the infusion of nut-galls throws it down yellow: if any iron be present the colour of the precipitate is purplish. Ferrochyazate of potash throws it down white, but if any iron be present, the tint is bluish.

The acetate of glucina is sweet and astringent, reddens vegetable blues, and does not crystallize, but forms a gummy mass in thin transparent plates, which dissolve in water.

The sulphate of glucina does not crystallize nor form alum. It forms a sulphate in flocks, and a supersulphate which remains in solution.

The carbonate of glucina loses half its weight when exposed to a red heat.‡

III. ALUMINA.

Properties.

Alumina obtained by the process formerly described,§ is a fine white-coloured powder destitute of taste and smell, but adhering strongly to the tongue. It is insoluble in water and

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* Vauquelin; Ann. du Mus. d'Hist. Nat. xv. 9.

† See vol. i. p. 371.

‡ Vauquelin; Ann. du Mus. d'Hist. Nat. xv. 9.

§ See vol. i. p. 373.

alcohol; but dissolves readily in caustic alkalies, and in a small degree it is soluble in ammonia, and even carbonate of ammonia. It dissolves slowly in sulphuric acid when assisted by heat, forming a colourless solution. When sulphate of potash is mixed with this solution, octahedral crystals of alum gradually form in it.

Alumina is not precipitated by ferrochyazate of potash, but the infusion of nut-galls throws it down white. The precipitate is redissolved by nitric acid.

Alumina undergoes a diminution of bulk proportional to the heat to which it is exposed. This contraction seems owing, in low temperatures, to the loss of moisture: but in high temperatures it must be owing to a more intimate combination of the earthy particles with each other; for it loses no perceptible weight in any temperature, however high, after being exposed to a heat of 130° Wedgewood.*

Wedgewood's pyrometer.

Mr. Wedgewood took advantage of this property of alumina, and by means of it constructed an instrument for measuring high degrees of heat. It consists of pieces of clay of a determinate size, and an apparatus for measuring their bulk with accuracy: one of these pieces is put into the fire, and the temperature is estimated by the contraction of the piece.† The contraction of the clay-pieces is measured by means of two brass rules fixed upon a plate. The distance between which at one extremity is 0·5 inch, and at the other extremity 0·3 inch, and the rules are exactly 24·0 inches in length, and divided into 240 equal parts, called degrees. These degrees commence at the widest end of the scale. The first of them indicates a red heat, or 947° Fahrenheit. The clay-pieces are small cylinders, baked in a red heat, and made so as to fit 1° of the scale. They are not composed of pure alumina, but of a fine white clay.

Unfortunately the contraction of these pieces is not always proportional to the degree of heat to which they have been exposed, nor do they correspond exactly with each other. The instrument, notwithstanding, is certainly valuable, and has contributed considerably towards the extension of our knowledge.

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* Jour. de Phys. lii. 287.

† See a particular description of this thermometer in Phil. Trans. lxii. and lxiv.

Alumina, when exposed to a very violent heat, produced by directing a stream of oxygen gas upon burning charcoal, undergoes a commencement of fusion, and is converted into a white enamel, semitransparent, and excessively hard.* If we put any confidence in the calculation of Saussure, the temperature necessary for producing this effect is as high as 1575° Wedgewood.†

Though alumina be insoluble in water, yet it has a strong affinity for that liquid, and when precipitated from its solution in acids, it is always obtained in the state of a *hydrate.* From Saussure's experiments there is reason to suspect that this hydrate is a compound of 1 atom alumina + 2 atoms water, or that it consists by weight of

Alumina	2·125	100
Water	2·25	105·88

Even this combination of alumina and water is capable, in its usual state of dryness, of absorbing $2\frac{1}{2}$ times its weight of water, without suffering any to drop out. It retains this water more obstinately than any of the other earths. In a freezing cold it contracts more, and parts with more of its water, than any other earth; a circumstance which is of some importance in agriculture.‡

II. The action of the simple supporters on alumina has not been examined.

Action of combustibles.

III. The action of the simple combustibles likewise is but imperfectly known. We are acquainted with no combination which they are capable of forming with alumina. But this earth has a strong affinity for metallic oxides, especially for those oxides which contain a maximum of oxygen. Some of these compounds are found native. Thus, the combination of alumina and red oxide of iron often occurs in the form of a yellow powder, which is employed as a paint, and distinguished by the name of *ochre.*

Alkalies.

IV. There is a strong affinity between the fixed alkalies and alumina. When heated together, they combine and form a loose mass without any transparency. Liquid fixed alkali dissolves alumina by the assistance of heat, and retains it in solution. The alumina is precipitated again unaltered, by

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* Morveau, Jour. de l'Ecole Polytechnique, I. iii. 299.

† Jour. de Phys. 1794.

‡ Kirwan's Miner. i. 9.

dropping an acid into the solution. This is the method employed by chemists to procure alumina in a state of complete purity; for alumina, unless it be dissolved in alkali, almost always retains a little oxide of iron and some acid, which disguise its properties. Liquid ammonia is also capable of dissolving a very minute proportion of newly precipitated alumina.

Barytes and strontian.

Barytes and strontian also combine with alumina, both when heated with it in a crucible, and when boiled with it in water. The result, in the first case, is a greenish or bluish-coloured mass, cohering but imperfectly: in the second, two compounds are formed; the first, containing an excess of alumina, remains in the state of an insoluble powder; the other, containing an excess of barytes or strontian, is held in solution by the water.*

Lime.

Alumina has a strong affinity for lime, and readily enters with it into fusion. The effect of heat on various mixtures of lime and alumina will appear from the following table.†

Proportions.	Heat.	Effect.
75 Lime 25 Alumina	150° Wedg.	Not melted.
66 Lime 33 Alumina	150	Remained a powder.
33 Lime 66 Alumina	‡	Melted.
25 Lime 75 Alumina	‡	Melted.
20 Lime 80 Alumina	‡	Melted.

Magnesia.

Magnesia and alumina have no action whatever on each other, even when exposed to a heat of 150° Wedgewood.§

From the experiments of Achard, it appears, that no mixture of lime, magnesia, and alumina, in which the lime predominates, is vitrifiable, except they be nearly in the proportions of three parts lime, two magnesia, one alumina; that no mix-

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* Vauquelin, Ann. de Chim. xxix. 270. See also Bucholz's Beitrage, iii. 58.

† Kirwan, i. 65.

‡ These three experiments were made by Ehrman: the heat was produced by directing a stream of oxygen gas on burning charcoal, and is the most intense which it has been hitherto possible to produce.

§ Kirwan's Miner. i. 57.

ture in which magnesia predominates will melt in a heat below 166°; that mixtures in which the alumina exceeds are generally fusible, as will appear from the following table.*

3 Alumina 2 Lime 1 Magnesia	A porcelain.
3 Alumina 1 Lime 2 Magnesia	A porcelain.
3 Alumina 1 Lime 3 Magnesia	Porous porcelain.
3 Alumina 2 Lime 3 Magnesia	Porous porcelain
3 Alumina 2 Lime 2 Magnesia	Porcelain.

None of the earths is of more importance to mankind than alumina; it forms the basis of china and stoneware of all kinds, and of the crucibles and pots employed in all those manufactures which require a strong heat. It is absolutely necessary to the dyer and calico-printer, and is employed too with the greatest advantage by the fuller and cleaner of cloth.

IV. ZIRCONIA.

Properties.

Zirconia, obtained by the process described in a former part of this work,† is a white powder, having a harsh feel, destitute of taste and smell, and insoluble in water, alcohol, and fixed alkalies. But it dissolves in the solutions of the alkaline carbonates.

The salts of zirconia have an astringent taste. The nitrate and acetate do not crystallize: but form a gummy-like matter; the muriate crystallizes, and is very soluble. The sulphate and carbonate are insoluble in water.

Zirconia is precipitated from its solutions by prussiate of potash, gallic acid, and infusion of nut-galls.

This earthy body, on account of its scarcity, has been more imperfectly examined than any of the others.

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* Kirwan's Miner. i. 72.

† See vol. i. p. 375.

V. THORINA.

Subdivis. I. Chap. II.

Thorina, obtained by the process described in a former part of this work,* is a white powder still capable of dissolving in acids, though it has been exposed to a red heat. Its salts have a purely astringent taste, without any sweetness or bitterness. All its saline solutions are precipitated by boiling when they do not contain a great excess of acid. It is insoluble in the aqueous solution of potash.

It is precipitated white by ferrochyazate of potash, oxalate of ammonia, tartrate of ammonia, benzoate of ammonia.

SECT. V.

OF THE METALLIC OXIDES.

Number.

THESE are the oxides of the three last families in the second genus of simple combustibles. They amount to twenty metals; five of which, namely, zinc, cadmium, bismuth, silver, and palladium, form only one oxide. All the rest, it would seem, form two oxides each. In iron, manganese, lead, and rhodium, the two oxides combine, and form peculiar compounds, which might be considered as intermediate oxides were it not that they do not unite with acids, but are separated, by these liquids, into protoxides and peroxides. In iron, nickel, cobalt, manganese, cerium, uranium, and lead, it is the protoxides that possess the alkaline qualities in greatest perfection, or, in other words, have the greatest tendency to unite with and neutralize acids. In copper and gold, and probably also in platinum, the peroxides have a greater tendency to neutralize acids than the protoxides. In mercury and rhodium, both the protoxide and peroxide neutralize acids. Iridium has not been sufficiently examined to enable us to determine its oxides, or which possesses most of the neutralizing power. The oxides of tin possess the property of uniting with acids in a very imperfect degree. They are nearly as capable of combining with alkaline bodies. So that they constitute the limit, as it were, between acid and alkaline bodies.

Nature.

None of the metallic oxides belonging to this section have the property of changing vegetable blues to green. The rea-

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* See vol. i. p. 377.

Book II. Division I.

son seems to be that they are insoluble in water. For several of them possess the property of neutralizing acids as completely as the fixed alkalies themselves. This is the case with the oxide of silver, the protoxide of lead, the oxide of zinc, the protoxide of manganese. The alkaline power of protoxide of iron, protoxide of nickel, protoxide of cobalt, peroxide of copper is also great, though perhaps inferior to that of the first-mentioned oxides. The oxide of bismuth is inferior in neutralizing powers to the peroxide of copper. I have not sufficient knowledge of the neutralizing powers of protoxide of cerium, protoxide of uranium, peroxide of gold, and peroxide of platinum, to assign them their true place. The neutralizing power of protoxide of cerium is considerable, probably not inferior to that of protoxide of iron. Both oxides of mercury possess considerable neutralizing powers.

I have already described the properties of these oxides, and given a table of their composition when treating of the metals themselves from which they are obtained. When we wish to dissolve them in acids, we should employ them in the state of hydrates. After being exposed to a red heat they lose a great deal of their solubility, no doubt in consequence of the great increase of the cohesion of their particles.

CHAP. III.

OF ACIDS.

THE word ACID, originally synonimous with SOUR, and applied only to bodies distinguished by that taste, has been gradually extended in its signification by chemists, and now comprehends under it all substances possessed of the following properties:

Properties.

1. When applied to the tongue, they excite that sensation which is called *sour* or *acid*.

2. They change the blue colours of vegetables to a red. The vegetable blues employed for this purpose are generally infusion of litmus and syrup of violets or raddishes, which have obtained the name of *reagents* or *tests*. If these colours have been previously converted to a *green* by alkalies, the acids restore them again.

3. They unite with water in almost any proportion.

4. They combine with alkalies, earths, and most of the me-

tallic oxides, and form with them those compounds which are called *salts*.

It must be remarked, however, that every acid does not possess all these properties; but all of them possess a sufficient number of them to distinguish them from other substances. And this is the only purpose which artificial definition is meant to answer.

The acids are by far the most important class of bodies in chemistry. It was by their means indeed, by studying their properties, and by employing them as instruments in the examination of other bodies, that men of science laid the foundation of chemistry, and brought it to that state in which we find it at present. The nature and composition of acids, therefore, became a very important point of discussion, and occupied the attention of the most eminent cultivators of the science.

Opinion concerning the acid principle.

Paracelsus believed that there was only one acid principle in nature which communicated taste and solubility to the bodies in which it was combined. Beecher embraced the same opinion; and added to it, that this acid principle was a compound of earth and water, which he considered as two elements. Stahl adopted the theory of Beecher, and endeavoured to prove that this acid principle is sulphuric acid; of which, according to him, all the other acids are mere compounds. But his proofs were only conjectures or vague experiments, from which nothing could be deduced. Nevertheless, his opinion, like every other which he advanced in chemistry, continued to have supporters for a long time, and was even countenanced by Macquer. At last its defects began to be perceived: Bergman and Scheele declared openly against it; and their discoveries, together with those of Lavoisier, demonstrated the falsehood of both parts of the theory, by showing that sulphuric acid does not exist in the other acids, and that it is not composed of water and earth, but of sulphur and oxygen.

The opinion, however, that acidity is owing to some principle common to all the salts, was not abandoned. Wallerius, Meyer, and Sage had advanced different theories in succession about the nature of this principle; but as they were founded rather on conjecture and analogy than direct proof, they obtained but few advocates. At last Mr. Lavoisier, by a number of ingenious and accurate experiments, proved that several combustible substances, when united with oxygen, form acids;

Supposed oxygen,

that a great number of acids contain oxygen ; and that when this principle is separated from them, they lose their acid properties. He concluded, therefore, that the acidifying principle is oxygen, and that acids are nothing else but combustible substances combined with oxygen, and differing from one another according to the nature of the combustible base.

This opinion, like most of those advanced by M. Lavoisier, was very generally received by chemists; though there were some who refused to admit it, and contended that no such substance as an acidifying principle exists; but that the nature of a compound depends upon the way in which the constituents unite together. This was the opinion maintained all along by Berthollet; and the authority of his name, which was deservedly high, prevented the hypothesis of Lavoisier from being adopted with so much keenness, or insisted on with so much violence, as would have been otherwise the case.

But erroneously.

The curious experiments on chlorine, by Gay-Lussac and Thenard, the new view of the nature of muriatic acid taken in consequence by Sir Humphrey Davy, the subsequent discovery of hydriodic acid, and of hydrocyanic acid, have made so great an alteration in our knowledge of acids, that Lavoisier's hypothesis can now have few or no supporters, and the opinion of Berthollet, respecting the nature of acidity, promises fairest to be the true one.

All the acids at present known, with the exception of three, namely, sulphuretted hydrogen, telluretted hydrogen, and seleniuretted hydrogen, contain a supporter of combustion. By far the greater number of known acids contain oxygen. All acids, therefore (with the exception of the three abovenamed) are combinations of supporters and combustibles. Now there are some that contain only one combustible, which may be considered as the base; while others contain two combustibles, or even three, united to a supporter. It has not been ascertained whether these last consist of a compound combustible basis united to a supporter; so that with respect to them we cannot say that they possess any acidifying principle whatever.

Division.

In this chapter I shall describe all the known acids that consist of oxygen united to a combustible, or to combustibles. It will be convenient to distinguish these two sets of acids from each other. The second set is derived entirely from the vegetable and animal kingdom, and consists of acids that are capable of undergoing combustion, and which are destroyed by fire, as is the case with all organic bodies, whether vegetable or animal; whereas the first set are incombustible, and may be exposed to a considerable heat without undergoing decomposition. We shall, therefore, divide the acids containing oxygen into *two genera.* The first genus will consist of the acids formed by the combination of oxygen with a single combustible; the second, of those that contain oxygen united to two or more combustibles.

GENUS I. ACIDS WITH A SIMPLE BASIS.

All the simple acidifiabic combustibles are capable of forming acids with oxygen, except hydrogen and tellurium. The whole of the third genus of combustibles likewise form acids with oxygen, except titanium. The acids therefore belonging to this genus including those of azote amount to 22 in number. Their names are as follows:

	Bases.
Nitric acid	Azote.
Nitrous acid	
Carbonic acid	Carbon.
Boracic acid	Boron.
Silica	Silicon.
Phosphoric acid	Phosphorus.
Phosphorous acid	
Hypophosphorous acid	
Sulphuric acid	Sulphur.
Sulphurous acid	
Hyposulphurous acid	
Hyposulphuric	
Selenic	Selenium.
Arsenic acid	Arsenic.
Arsenious acid	
Antimonic acid	Antimony.
Antimonious acid	
Chromic acid	Chromium.
Molybdic acid	Molybdenum.
Molybdous acid	
Tungstic acid	Tungsten.
Columbic acid	Columbium.

When these acids contain as much oxygen as can unite with their bases, their names terminate in *ic*, when the bases are not saturated with oxygen the name of the acid terminates in *ous*.

We shall describe the properties of these acids in the following sections.

SECT. I.

OF NITRIC ACID.

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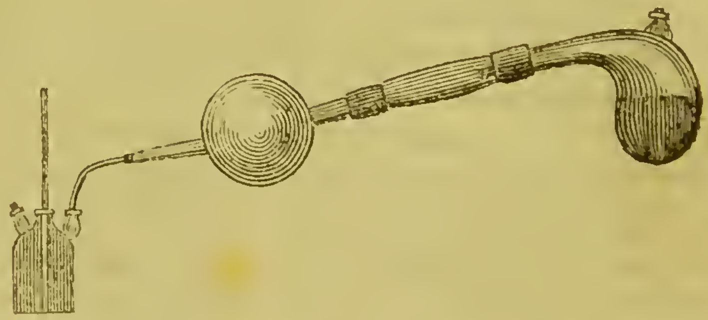
NITRIC acid seems to have been first obtained in a separate state by Raymond Lully, who was born at Majorca in 1235. He procured it by distilling a mixture of nitre and clay. Basil Valentine, who lived in the 15th century, describes the process minutely, and calls the acid *water of nitre.* It was afterwards denominated *aqua fortis* and *spirit of nitre.* The name *nitric acid* was first given it in 1787 by the French chemists.

Preparation.

1. It was formerly obtained in large manufactories by distilling a mixture of nitre and clay; but the acid procured by this process is weak and impure. Chemists generally prepare it by distilling 2 parts of nitre and 1 of sulphuric acid in a glass retort. This method was first used by Glauber. The neck of the retort must be luted into a receiver, from which there passes a glass tube into a bottle with two mouths, containing a little water, and furnished with a tube of safety.* From the other mouth of this bottle there passes a tube into a pneumatic apparatus to collect the gas which is evolved during the process. The apparatus is represented in the following figure:



The retort is to be heated gradually to at least 500°. The

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[*] A tube of safety is a tube open at its upper end, and having its lower end plunged in water. The water prevents any communication between the external air and the inside of the apparatus. If a vacuum happens to be formed within the vessels, the external air rushes down through the tube and prevents any injury to the vessels. On the other hand, if air is generated in the vessels, it forces the water up to the tube, the height of which becomes thus the measure of the elasticity of the air in the vessels. By this contrivance the apparatus is in no danger of being broken, which otherwise might happen.

nitric acid comes over and is condensed in the receiver, while the common air of the vessels, and a quantity of oxygen gas which is evolved, especially towards the end of the process, passes into the pneumatic apparatus, and the water in the bottles is impregnated with some acid which is not condensed in the receiver.

The acid, thus obtained, is of a yellow colour, and almost always contains muriatic and sulphuric acid from which it is difficult to free it completely. Perhaps the best way is to purify the nitre beforehand by repeated crystallizations, and by throwing down the muriatic acid that may adhere after all, by means of nitrate of silver. From the experiments of Lassone and Cornette, it appears that if nitric acid contaminated with muriatic be distilled with precaution, the whole of the muriatic acid comes over with the first portions, and the last portions are quite free from it.* The common method is to mix impure nitric acid with nitrate of silver, to separate the precipitate, and re-distil. This method succeeds only when the acid is strong; if it be weak, a portion of muriatic acid still adheres to it. The sulphuric acid may be separated by rectifying the acid, by distilling it slowly, and withholding the last portions, or by distilling it off litharge or nitrate of barytes.

After these foreign bodies are separated, the acid still retains a quantity of nitrous gas, to which it owes its colour and the red fumes which it exhales. This gas may be expelled by the application of heat. Pure *nitric acid* remains behind, transparent and colourless, like water.

Properties.

2. When newly prepared in this manner, it is a liquid as transparent and colourless as water; but the affinity between its component parts is so weak, that the action of light is sufficient to drive off a part of its oxygen in the form of gas; and thus, by converting it partly into nitrous gas, to make it assume a yellow colour. Its taste is exceedingly acid and peculiar. It is very corrosive, and tinges the skin of a yellow colour, which does not disappear till the epidermis comes off. It is constantly emitting white fumes, which have an acrid and disagreeable odour.

Action of water.

3. It has a strong affinity for water, and has never yet been obtained except mixed with that liquid. When concentrated, it attracts moisture from the atmosphere, but not so powerfully

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* Mem. Par. 1781, p. 645

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as sulphuric acid. It also produces heat when mixed with water, owing evidently to the concentration of the water.

The specific gravity of the strongest nitric acid that can be procured is, according to Rouelle, 1·583; but at the temperature of 60°, Mr. Kirwan could not procure it stronger than 15543. Proust obtained it of a specific gravity as high as 1·62.*

As nitric acid, however much it may be concentrated, always contains water combined with it, it becomes a problem of considerable interest to ascertain the proportion of real acid, or of acid destitute of water, that exists in nitric acid of every specific gravity. This problem has exercised the ingenuity of Kirwan,† Davy,‡ Berthollet,§ and Dalton.||

The following table drawn up by Dr. Ure, from a set of experiments that seem to have been made with care, must prove of considerable utility to practical chemists:

Specific gravity.	Acid in 100.	pecific ravity.	Acid in 100.	Specific gravity.	Acid in 100.
1·5000	79·700	1·4424	64·557	1·3579	49·414
1·4980	78·903	1·4385	63·760	1·3529	48·617
1·4960	78·106	1·4346	62·963	1·3477	47·820
1·4940	77·309	1·4306	62·166	1·3427	47·023
1·4910	76·512	1·4269	61·369	1·3376	46·226
1·4880	75·715	1·4228	60·572	1·3323	45·429
1·4850	74·918	1·4189	59·775	1·3270	44·632
1·4820	74·121	1·4147	58·978	1·3216	43·835
1·4790	73·324	1·4107	58·181	1·3163	43·038
1·4760	72·527	1·4065	57·384	1·3110	42·241
1·4730	71·730	1·4023	56·587	1·3056	41·444
1·4700	70·933	1·3978	55·790	1·3001	40·647
1·4670	70·136	1·3945	54·993	1·2947	39·850
1·4640	69·339	1·3882	54·196	1·2887	39·053
1·4600	68·542	1·3833	53·399	1·2826	38·256
1·4570	67·745	1·3783	52·602	1·2765	37·459
1·4530	66·948	1·3732	51·805	1·2705	36·662
1·4500	66·155	1·3681	51·068	1·2644	35·865
1·4460	65·354	1·3630	50·211	1·2583	35·068

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* Jour. de Phys. 1799, as quoted by Mr. Dalton in his New System of Chemical Philosophy, ii. 315.

† Irish Transactions, iv. 1.

‡ Researches, p. 41.

§ Jour. de Phys. 1807, March.

|| New System of Chemical Philosophy, ii. 355.

TABLE—*continued.*

Specific gravity.	Acid in 100.	Specific gravity.	Acid in 100.	Specific gravity.	Acid in 100.
1·2523	34.271	1·1587	22·316	1·0708	10·361
1·2462	33·474	1·1526	21·519	1·0651	9·564
1·2402	32·677	1·1465	20·722	1·0595	8·767
1·2341	31·880	1·1403	19·925	1·0540	7·970
1·2277	31·083	1·1345	19·128	1·0485	7·173
1·2212	30·286	1·1286	18·331	1·0430	6·376
1·2148	29·489	1·1227	17·534	1·0375	5·579
1·2084	28·692	1·1168	16·737	1·0320	4·782
1·2019	27·895	1·1109	15·940	1·0267	3·985
1·1958	27·098	1·1051	15·143	1·0212	3·188
1·1895	26·301	1·0993	14·346	1·0159	2·391
1·1833	25·504	1·0935	13·549	1·0106	1·594
1·1770	24·707	1·0878	12·752	1·0053	0·797
1·1709	23·910	1·0821	11·955		
1·1648	23·113	1·0764	11·158		

The following table exhibits the constitution of nitric acid of various densities.

Specific gravity.		Acid.		Water.
1·485	is composed of	1 atom	+	2 atoms.
1·450	....	1	.... +	3
1·419	....	1	....	4
1·394	....	1	....	5
1·360	....	1	....	6
1·337	....	1	....	7
1·316	....	1	....	8
1·295	....	1	....	9
1·276	....	1	....	10
1·260	....	1	....	11
1·246	....	1	....	12

Probably the specific gravity of a compound of 1 atom acid + 1 atom water, would be about 1·5945.

4. From the experiments of Mr. Dalton it appears that the boiling point of nitric acid is a maximum when it is of the specific gravity 1·42. It then boils at the temperature of 248°, as had been already ascertained by Bergman.* When either

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* Opusc. ii. 141.

stronger or weaker, the temperature at which it begins to boil is diminished. The following table drawn up by Mr. Dalton, from his own experiments, shows the temperature at which acid of different densities begins to boil.*

Boiling point.

Sp. gravity of acid.	Boiling point.
1·62	100°?
1·54	175
1·50	210
1·45	240
1·42	248
1·40	247
1·35	242
1·30	236
1·26	232
1·22	229
1·20	226
1·18	223
1·17	221
1·16	220
1·15	219
1·14	219

When cooled down to − 66°, it begins to congeal; and when agitated, it is converted into a mass of the consistence of butter.† But an account of the freezing points of this acid, as ascertained by Cavendish, has been already given in a preceding part of this work. ‡

II. The simple supporters of combustion have no action on nitric acid; at least as far as is known at present.

Action of combustibles.

III. All the simple combustibles decompose it, except the diamond, gold, platinum, palladium, rhodium, and tantalum. When poured upon sulphur or phosphorus § at a high temperature, it sets them on fire; but at a moderate temperature it converts them slowly into acids, while nitrous gas is exhaled. It inflames charcoal also at a high temperature, and even at

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* New System of Chemical Philosophy, ii. 355.

† Fourcroy and Vauquelin, Ann. de Chim. xxix. 282.

‡ Vol. i. p. 50.

§ According to Brugnatelli, when a bit of phosphorus is wrapped up in paper, dipped in nitric acid, and struck smartly with a hammer upon an anvil, a detonation takes place. Jour. de Chim. iv. 113.—With me, however, the experiment did not succeed.

the common temperature, provided the charcoal be perfectly dry and minutely divided.* Hydrogen gas produces no change on it at the temperature of the atmosphere; but when passed along with it through a red hot porcelain tube, it detonates with great violence; water is formed, and azotic gas evolved.†

When this acid is poured upon oils, it sets them on fire. This is occasioned by a decomposition both of the acid and oil. The oxygen of the acid combines with the carbon and with the hydrogen of the oils, and at the same time lets out a quantity of caloric. Hence we see that the oxygen which enters into the composition of the nitric acid still contains a great deal of caloric; a fact which is confirmed by a great number of other phenomena. The combustion of oils by this acid was first taken notice of by Borrichius and Slare;‡ but it is probable that Homberg communicated it to Slare. In order to set fire to the fixed oils, it must be mixed with some sulphuric acid; the reason of which seems to be, that these oils contain *water*, which must be previously removed. The sulphuric acid combines with this water, and allows the nitric acid, or rather the oil and nitric acid together, to act. The drying oils do not require any sulphuric acid: they have been boiled, and consequently deprived of all moisture.

It sets fire to zinc, bismuth, and tin, if it be poured on them in fusion, and to filings of iron if they be perfectly dry. §

IV. Nitric acid absorbs nitrous gas with great avidity, assumes a yellow or brown colour, and the property of emitting dense yellow fumes. In this state it was formerly known by the name of *phlogisticated nitric acid*.

Nitrates.

V. Nitric acid combines with alkalies, earths, and the oxides of metals, and forms compounds which are called *nitrates*.

VI. Nitric acid is one of the most important instruments of analysis which the chemist possesses; nor is it of inferior consequence when considered in a political or commercial view, as it forms one of the most essential ingredients of gunpowder. Its nature and composition accordingly have long occupied the attention of philosophers. Let us endeavour to trace the various steps by which its component parts were discovered.

Composition.

As nitre is often produced upon the surface of the earth, and never except in places which have a communication with

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[*] Proust.

[†] Fourcroy, ii. 82.

[‡] Phil. Trans. Abr. ii. 653, and iii. 663.

[§] Proust, Dijon Academicians, and Cornette.

atmospheric air, it was natural to suppose that air, or some part of the air, entered into the composition of nitric acid. Mayow having observed, that nitre and atmospherical air were both possessed of the property of giving a red colour to the blood, and that air was deprived of this property by combustion and respiration—concluded that nitre contained that part of the air which supported combustion, and was necessary for respiration.

Dr. Hales, by applying heat to nitric acid, and what he called *Walton mineral*, obtained a quantity of air possessed of singular properties. When atmospherical air was let into the jar which contained it, a reddish turbid fume appeared, a quantity of air was absorbed, and the remainder became transparent again.* Dr. Priestley discovered, that this air could only be obtained from nitric acid; and therefore called it *nitrous air*. He found, that when this gas was mixed with oxygen gas, nitric acid was reproduced. Here, then, we find that oxygen is a part of the nitric acid, and consequently that Mayow's affirmation is verified.

Dr. Priestley, however, explained this fact in a different manner. According to him, nitrous gas is composed of nitric acid and phlogiston. When oxygen is added, it separates this phlogiston, and the acid of course is precipitated. This hypothesis was adopted by Macquer and Fontana; and these three philosophers endeavoured to support it with their usual ingenuity. But there was one difficulty which they were unable to surmount. When the two gases are mixed in proper proportions, almost the whole assumes the form of nitric acid; and the small residuum ($\frac{1}{34}$th part), in all probability, or rather certainly, depends on some accidental impurity in the two gases. What then becomes of the oxygen and phlogiston? Dr. Priestley supposed that they formed carbonic acid gas; but Mr. Cavendish proved, that when proper precautions are taken, no such acid appears.†

Dr. Priestley had procured his nitrous gas by dissolving metals in nitric acid; during the solution of which a great deal of nitrous gas escapes. He supposed that nitrous gas contained phlogiston, because the metal was oxidized (and consequently, according to the then received theory, must have lost phlogiston) during its formation. M. Lavoisier proved, that this supposition was ill founded, by the following cele-

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* Veget. Statics, ii. 284.

† Phil. Trans. 1784.

brated experiment.* To 945 grains of nitric acid (specific gravity 1·316) he added 1104 grains of mercury. During the solution 273·234 cubic inches of nitrous gas were produced. He then distilled the salt (oxide of mercury) which had been formed to dryness. As soon as it became red hot it emitted oxygen gas, and continued to do so till almost the whole of the mercury was revived: the quantity of oxygen emitted was 287·742 cubic inches. All that had happened, therefore, during the solution of the mercury, was the separation of the acid into two parts; nitrous gas, which flew off, and oxygen, which united with the metal.

M. Lavoisier concluded, therefore, that the whole of the nitrous gas was derived from the nitric acid; that nitric acid is composed of oxygen and nitrous gas; and that the proportions are nearly 64 parts by weight of nitrous gas, and 36 of oxygen gas.

But there was one difficulty which M. Lavoisier acknowledged he could not remove. The quantity of oxygen obtained by decomposing nitric acid was often much greater than what was necessary to saturate the nitrous gas. M. De Morveau attempted to account for this; but without success.† Nitrous gas itself was evidently a compound: but the difficulty was to discover the ingredients. M. Lavoisier concluded, from an experiment made by decomposing nitre by means of charcoal, that it contained azote; and several of Dr. Priestley's experiments led to the same result. But what was the other ingredient?

Mr. Cavendish had observed, while he was making experiments on the composition of water, that some nitric acid was formed during the combustion of oxygen and hydrogen gas, and that its quantity was increased by adding a little azote to the two gases before the explosion. Hence he concluded, that the formation of the acid was owing to the accidental presence of azotic gas. To verify this conjecture, he passed electrical sparks through a quantity of common air inclosed in a glass tube: the air was diminished, and some nitric acid formed. He repeated the experiment, by mixing together oxygen and azotic gas; and found, that when they bore a certain proportion to each other they were totally convertible into nitric acid.

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* Mem. Par. 1776, p. 673.

† Encyc. Method. Chim. Acide Nitrique.

These experiments were immediately repeated by Messrs. Van Marum and Van Troostwyk, and with nearly the same result.

Dr. Priestley had observed, several years before these experiments were made, that atmospherical air was diminished by the electric spark, and that during the diminution the infusion of turnsol became red; but he concluded merely that he had precipitated the acid of the air. Landriani, who thought, on the contrary, that carbonic acid gas was formed, announced the alteration of lime-water by it as a proof of his opinion. It was to refute this notion that Mr. Cavendish undertook his experiments.

It cannot be doubted, then, that nitric acid is composed of azote and oxygen; consequently nitrous gas is also composed of the same ingredients. And as nitrous gas absorbs oxygen, even from common air, and forms with it nitric acid, it is evident that nitric acid contains more oxygen than nitrous gas. But it is exceedingly difficult to ascertain the exact proportions of the component parts of this acid. The subject has been discussed with much care of late by Berzelius, Dalton, Davy, and Gay-Lussac. I have given in a former part of this work the composition of this acid as deduced from the most accurate experiments hitherto made and now generally adopted by chemists. It is composed of 1 volume of azotic gas combined with 2½ volumes of oxygen gas, or of 1 atom azote + 5 atoms oxygen, or by weight of

Azote..	1·75	100	25·93
Oxygen	5·00	285·8	74·07
			100·00

SECT. II.

OF NITROUS ACID.

Discovery.

When nitre, which is a compound of nitric acid and potash, is exposed to a red heat, it yields a considerable quantity of oxygen gas almost in a state of purity. If the process be conducted with the proper precautions and stopped in time, the nitre still retains the properties of a neutral salt. But the acid which it contains is obviously in a different state, since it has lost a considerable part of its oxygen. To this new state the term *nitrous acid* is applied.

The experiment just recited was first made by Scheele, and mentioned in his dissertation on manganese, published in 1774.* He first pointed out the difference between *nitric* and *nitrous* acids.

Berzelius first observed that when dry nitrate of lead is distilled in a glass retort there comes over an orange coloured liquid. This liquid was examined by Gay-Lussac,† and afterwards more carefully by Dulong.‡ It is *nitrous acid* nearly pure.

Properties.

Nitrous acid, thus prepared, has an orange colour; its taste is very acid; it smokes strongly, and is very volatile, boiling at the temperature of 82°. Its specific gravity is 1·451. When passed over red hot iron or copper it is decomposed. The oxygen unites to the metals while the azote is set at liberty. From the experiments of Gay-Lussac, there is reason to conclude that this acid may be formed by mixing together 1 volume of oxygen gas with 2 volumes of nitrous gas. Hence it must be composed by weight of

Azote	1·75	100
Oxygen	4	228·57

When this acid is mixed with water an effervescence takes place and nitrous gas is emitted. Hence it appears that nitrous acid cannot exist in combination with water. The different high-coloured acids, therefore, to which the name of *nitrous acid* has been applied are not entitled to that name; they consist rather of nitric acid, holding in solution various proportions of nitrous gas. The nature of this high-coloured acid was first investigated by Dr. Priestley, who demonstrated, by very decisive experiments, that it is a compound of nitric acid and nitrous gas. This opinion was embraced, or rather it was first fully developed, by Morveau.§ But the theory of Lavoisier, which supposed the difference between colourless and yellow nitric acid to depend merely on the first containing a greater proportion of oxygen than the second, for some time drew the attention of chemists from the real nature of the combination. Raymond published a dissertation in 1796, to demonstrate the truth of the theory of Priestley and Mor-

Coloured nitric acid.

A compound of nitric acid and nitric oxide.

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* Scheele's Opusc. i. 59.

† Ann. de Chim. et Phys. i. 405.

‡ Ann. de Chim. ii. 317.

§ Encyc. Method. Chim. i. 18.

veau; and the same thing was done still more lately by Thomson and Davy.*

Nitric acid being capable of absorbing very different proportions of nitrous gas, it is evident that there must be a great variety of *nitrous acids*, to use the common phrase, differing from each other in the proportion of nitrous gas which they contain; unless we choose to confine the term to the compound formed by saturating nitric acid completely with nitrous gas.

When nitrous gas is placed in contact with nitric acid, the acid absorbs it slowly, and acquires first a pale yellow colour, then a bright yellow: when a considerable portion more of nitrous gas is absorbed, the acid becomes dark orange, then olive, which increases in intensity with the gas absorbed; then it becomes of a bright green; and lastly, when fully saturated, it becomes blue green. Its volume and its volatility also increase with the quantity of gas absorbed; and, when fully saturated, it assumes the form of a dense vapour, of an exceedingly suffocating odour, and difficultly condensible by water. In this state of saturation it is distinguished by Dr. Priestley by the name of *nitrous acid vapour*. It is of a dark red colour, and passes through water partly without being absorbed. The quantity of nitrous gas absorbed by nitric acid is very great. Dr. Priestley found that a quantity of acid, equal in bulk to four pennyweights of water, absorbed 130 ounce measures of gas without being saturated.† The component parts of nitrous acid, of different colours and densities, has been determined by Sir H. Davy, as in the following table: ‡

Varieties.

100 Parts.	Sp. grav.	Component Parts.		
		Nitric acid.	Water.	Nitrous Gas.
Solid nitric acid . .	1·504	91·55	8·45	—
Yellow nitrous. . . .	1·502	90·5	8·3	2
Bright yellow	1·500	88·94	8·10	2·96
Dark orange.	1·480	86·84	7·6	5·56
Light olive	1·479	86·00	7·55	6·45
Dark olive	1·478	85·4	7·5	7·1
Bright green	1·476	84·8	7·44	7·76
Blue green	1·475	84·6	7·4	8·00

* Davy's Researches, p. 30.

† Priestley, i. 383.

‡ Davy's Researches, p. 37.

The colour of nitric acid depends, in some measure, also on the proportion of water which it contains. When to yellow nitric acid concentrated, a fourth part by weight of water is added, the colour is changed to a fine green; and when equal parts of water are added, it becomes blue.* Dr. Priestley observed, that water impregnated with this acid in the state of vapour became first blue, then green, and lastly yellow. A green nitric acid became orange coloured while hot, and retained a yellow tinge when cold. A blue acid became yellow on being heated in a tube hermetically sealed. An orange coloured acid, by long keeping, became green, and afterwards of a deep blue; and when exposed to air, resumed its original colour. When yellow nitric acid is exposed to heat, the nitrous gas is expelled, and nitric acid remains behind. The gas, however, carries along with it a quantity of acid, especially if the acid be concentrated. But nitrous acid vapour is not altered in the least by exposure to heat.†

SECT. III.

OF CARBONIC ACID.

History.

As the rapid progress of chemistry, during the latter part of the 18th century, was very much connected with the discovery of this acid, it may be worth while to trace the history of it somewhat particularly.

Paracelsus and Van Helmont were acquainted with the fact, that air is extricated from limestone during certain processes, and the latter gave to air thus produced the name of *gas*. Hales ascertained the quantity of air that could be extricated from these bodies in different processes, and showed that it formed an essential part of their composition. Dr. Black proved that the substances then called *lime*, *magnesia*, and *alkalies*, are compounds, consisting of a *peculiar species of air*, and pure lime, magnesia, and alkali. To this species of air he gave the name of *fixed air*, because it existed in these bodies in a fixed state. This air or gas was afterwards investigated by Mr. Cavendish and Dr. Priestley, and a great number of its properties ascertained. From these properties Mr. Keir ‡ first concluded that it was an acid; and this opi-

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* Bergman.

† Fourcroy, ii. 95.

‡ Keir's Macquer, art. Air.

nion was soon confirmed by the experiments of Bergman, Fontana, &c. Dr. Priestley at first suspected that this acid entered as an element into the composition of atmospherical air; and Bergman, adopting the same opinion, gave it the name of *aerial acid.* Mr. Bewdly called it *mephitic acid,* because it could not be respired without occasioning death; and this name was also adopted by Morveau. Mr. Keir called it *calcareous acid;* and at last M. Lavoisier, after discovering its composition, gave it the name of *carbonic acid gas.*

For the investigation of the properties of carbonic acid we are chiefly indebted to the labours of Cavendish,* Priestley,† Bergman,‡ and Lavoisier.§ Valuable dissertations on it were also published by Macbride,|| Lane,** Jacquin,†† Landriani,‡‡ Fontana, and many other distinguished chemists. And within these few years very careful experiments have been made to determine its composition by Saussure,§§ Allen and Pepys,|||| and Davy.***

Preparation.

1. Carbonic acid, being a compound of carbon and oxygen, may be formed by burning charcoal; but as it exists in great abundance ready formed, there is no occasion to have recourse to that expedient. All that is necessary is to dilute with water a quantity of chalk, which is a compound of carbonic acid and lime, and to pour upon it sulphuric acid. An effervescence ensues, carbonic acid is evolved in the state of gas, and may be received in the usual manner.

Properties.

2. Carbonic acid, when in the state of gas, is invisible and elastic like common air. It extinguishes a candle, and is unfit for respiration. It has no smell.

Its specific gravity is 1·527, that of air being 1·000; or it is to air nearly as 3 to 2. From this considerable weight, compared to that of air, it happens that this gas may be poured from one vessel to another. When poured from a wide-mouthed vessel upon a burning candle, it extinguishes it like water.

It reddens the tincture of turnsol, but no other vegetable colour.†††

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* Phil. Trans. 1766, lvi. 141.

† Priestley, i. 43.

‡ Opusc. i. 1.

§ Mem. Par. 1776.

|| Experimental Essays, 1764.

** Priestley, i. 5.

†† Examen. Chem. Dict. Meyer, de Acido Pingui, et Blackianæ de Acre Fixo, 1769.

‡‡ Crell's Annals, 1785, ii. 139.

§§ Ann. de Chim. lxxi. 262.

|||| Phil. Trans. 1807.

*** Phil. Trans. 1814, p. 557.

††† Bergman, i. 9.

Atmospheric air is supposed to contain about $\frac{1}{1000}$ part of this gas.*

3. Carbonic acid is not altered by exposure to heat in close vessels, or by passing it through a red-hot tube. But when electric sparks are made to pass through it for a long time, its bulk is increased, as Dr. Priestley first observed; and in that case, as Mongez discovered, an inflammable gas is always evolved. By 18 hours labour Mr. Saussure, junior, produced an increase of $\frac{1}{130}$ part of the whole; one-tenth of the carbonic acid had disappeared, and a quantity of carbonic oxide had been formed. The copper wires employed to transmit the sparks were oxidized at the expense of the acid, which was thus partially converted into carbonic oxide.†

Action of water.

4. Water absorbs it gradually when allowed to remain long in contact with it. The rapidity of the absorption, as Mr. Lane first discovered, is much increased by agitation. At the temperature of 41° water absorbs its own bulk of this gas. According to the experiments of Mr. Cavendish, 100 measures of water of the temperature of 55° absorb 102·5 measures of carbonic acid.‡ According to Dr. Henry, 100 measures of water absorb 108 measures of this gas.§ According to Saussure, the quantity absorbed amounts to 106 measures.‖ Alcohol, according to Cavendish, absorbs $2\frac{1}{4}$ times its bulk of carbonic acid at the temperature of 46°. According to Saussure, 100 measures of alcohol, of the specific gravity 0·84, absorb 186 measures of carbonic acid gas. Probably the difference between these two results depends upon the difference of the temperature at which the absorption took place.

The specific gravity of water, saturated with carbonic acid gas, is 1·0015. This water, at the temperature of 35°, has little taste; but if it be left a few hours in the temperature of 88°, it assumes an agreeable acidity, and a sparkling appearance.**

Ice absorbs no carbonic acid; and if water containing it be

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* At least near the surface of the earth. Lamanon, Mongez, and the other unfortunate philosophers who accompanied La Perouse in his last voyage, have rendered it not improbable, that at great heights the quantity of this gas is much smaller. They could detect none in the atmosphere at the summit of the Peak of Teneriffe.—See Lamanon's Memoir at the end of La Perouse's Voyage.

† Phil. Mag. xiv. 350.

‡ Phil. Trans. 1766, p. 141.

§ Nicholson's Journal, vi. 229.

‖ Annals of Philosophy, vi. 340.

** Bergman, i. 9.

frozen, the whole separates in the act of freezing.* This gas also separates from water at the boiling temperature.†

By means of artificial pressure, the quantity of this gas absorbed and condensed in water is much increased. Some of the *aerated alkaline water*, prepared in Britain as a medicine, is said to contain about thrice its volume of carbonic acid gas.‡

When this liquid carbonic acid is left exposed to the air in an open vessel, the acid soon makes its escape in the form of gas, and leaves the water in a state of purity. Bergman left a bottle filled with carbonic acid gas uncorked, and found that in a few days it contained nothing but common air.

II. None of the simple supporters of combustion, so far as is known, have any action on carbonic acid.

Action of simple combustibles.

III. The action of the simple combustibles has been but little examined.

1. It is not improbable that hydrogen would decompose it at a red heat; but I do not know that the experiment has ever been tried.

2. Charcoal, at a red heat converts it into carbonic oxide, according to the experiments of Clement and Desormes.

3. Phosphorus is insoluble in carbonic acid gas;§ but phosphorus is capable of decomposing this acid by compound affinity, when assisted by a sufficient heat, as has been demonstrated by Tennant and Pearson. Iron also and zinc, and several other metals, are capable of producing the same effect, as has been discovered by Priestley and Cruickshanks. In the first case the phosphorus is partly acidified, partly combined with lime, and charcoal is deposited: in the second, the metals are oxidized, and the gaseous oxide of carbon evolved.

When carbonic acid is mixed with sulphuretted, phosphuretted, or carburetted hydrogen gas, it renders them less combustible, but produces no farther sensible change.

Carbonates.

IV. This acid is capable of combining with alkalies, and with several of the earths and metallic oxides, and forms with them salts, distinguished by the name of *carbonates*. All the earthy carbonates are insoluble in water. Hence the reason that carbonic acid renders lime water, barytes water, and strontian water turbid. The earth held in solution in these waters

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* Priestley, i. 120.

† Ibid.

‡ A very convenient apparatus for this purpose has been contrived by Mr. Gilbert Austin, and described in the Irish Transactions, viii. 131.

§ Fourcroy and Vauquelin, Nicholson's Jour. xxi. 205.

combines rapidly with the carbonic acid, which is of course absorbed, if in the state of gas, while the carbonate formed precipitates slowly in the form of a white powder. This occasions the milkiness which immediately ensues. As carbonic acid is the only gas not instantaneously absorbable by water, which renders lime water, or barytes or strontian water, turbid, its presence may be always ascertained by means of these liquids. As it is completely absorbed by them, it may be easily separated by them from other gases with which it may be mixed, and its quantity ascertained by the diminution of volume which the residuum of gas has undergone.

V. Water containing a little soda, and supersaturated with carbonic acid, has been employed with much advantage under the name of *aerated alkaline water*, as a palliative in cases of urinary calculus.

Composition.

VI. The opinions of chemists concerning the *composition* of carbonic acid have undergone as many revolutions as its name. Dr. Priestley and Bergman seem at first to have considered it as an element; and several celebrated chemists maintained that it was the acidifying principle. Afterwards it was discovered to be a compound, and that oxygen gas was one of its component parts. Upon this discovery the prevalent opinion of chemists was, that it consisted of oxygen and phlogiston; and when hydrogen and phlogiston came (according to Mr. Kirwan's theory) to signify the same thing, it was of course maintained that carbonic acid was composed of oxygen and hydrogen: and though M. Lavoisier demonstrated, that it was formed by the combination of carbon and oxygen, this did not prevent the old theory from being maintained; because carbon was itself considered as a compound, into which a very great quantity of hydrogen entered. But after M. Lavoisier had demonstrated, that the weight of the carbonic acid produced was precisely equal to the charcoal and oxygen employed; after Mr. Cavendish had discovered that oxygen and hydrogen when combined did not form carbonic acid, but water—it was no longer possible to hesitate that this acid was composed of carbon and oxygen. Accordingly all farther dispute about it has been long at an end. Its constituents as we have determined them in a preceding part of this work are

Carbon	0·75	100	27·27
Oxygen	2·	266·6	72·73
			100·00

Book II. Division I. Decomposition.

If any thing was still wanting to put this conclusion beyond the reach of doubt, it was to *decompound* carbonic acid, and thus to exhibit its component parts by analysis as well as synthesis. This has been actually done by Mr. Smithson Tennant. Into a tube of glass he introduced a bit of phosphorus and some carbonate of lime. He then sealed the tube hermetically, and applied heat. Phosphate of lime was formed, and a quantity of charcoal deposited. Now phosphate of lime is composed of phosphoric acid and lime; and phosphoric acid is composed of phosphorus and oxygen. The substances introduced into the tube were phosphorus, lime, and carbonic acid; and the substances found in it were phosphorus, lime, oxygen, and charcoal. The carbonic acid, therefore, must have been decomposed, and it must have consisted of oxygen and charcoal. This experiment was repeated by Dr. Pearson, who ascertained that the weight of the oxygen and charcoal were together equal to that of the carbonic acid which had been introduced: and in order to show that it was the carbonic acid which had been decomposed, he introduced pure lime and phosphorus; and instead of obtaining phosphate of lime and carbon, he got nothing but phosphuret of lime. These experiments* were also confirmed by Messrs. Fourcroy, Vauquelin, Sylvestre, and Broigniart.†

SECT. IV.

OF BORACIC ACID.

Preparation.

1. The easiest method of procuring boracic acid is the following one: dissolve borax in hot water, and filter the solution; then add sulphuric acid, by little and little, till the liquid has a sensibly acid taste. Lay it aside to cool, and a great number of small shining laminated crystals will form. These are the boracic acid. They are to be washed with cold water, and drained upon brown paper.‡

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* Ann. de Chim. xiii. 312.

† Count Mussin-Puschkin having boiled a solution of carbonate of potash on purified phosphorus, obtained charcoal. This he considered as an instance of the decomposition of carbonic acid, and as a confirmation of the experiments related in the text. See Ann. de Chim. xxv. 105.

‡ To extract the whole of the boracic acid, the solution should be evaporated after the first crop of crystals are obtained. When concentrated and set aside, an additional quantity of boracic acid falls down.

Properties.

2. Boracic acid, thus procured, is in the form of thin hexagonal scales, of a silvery whiteness, having some resemblance to spermaceti, and the same kind of greasy feel. It has a sourish taste* at first, then makes a bitterish cooling impression, and at last leaves an agreeable sweetness. It has no smell; but when sulphuric acid is poured on it, a transient odour of musk is produced.†

It reddens vegetable blues. Its specific gravity is 1·479‡ while in the form of scales; after it has been fused it is 1·803.§

3. It is not altered by light. It is perfectly fixed in the fire. At a red heat it melts, and is converted into a hard transparent glass; which becomes somewhat opaque when exposed to the air, but does not attract moisture.

Boracic acid in its common crystallized state is a hydrate, which according to the experiments of Sir H. Davy is composed of 57 acid + 43 water.|| Berzelius extracted from 100 parts of the acid, 44 parts of water. If we consider this last analysis as accurate, and I prefer it because it nearly coincides with my own experiments, and if we suppose farther that it is a compound of 1 atom of acid and two atoms of water, the weight of an atom of boracic acid will be 2·863. Were we to consider the weight of an atom of boracic acid to be 2·875, and to regard the scales as composed of 1 atom acid and 2 atoms water, their real constitution would be

Acid	56·1
Water	43·9
	100·0

Now I have not been able to satisfy myself that this is not the real constitution of the hydrate. The most careful experiments have not deviated above $\frac{1}{100}$th part from the theoretical numbers. Hence I consider myself as entitled to consider the weight of an atom of boracic acid to be 2·875, and to be a compound of

Composition.

Boron	0·875	100
Oxygen	2·000	228·57
	2·875	

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* Owing most probably to the remains of the acid employed in procuring it; for it loses that taste when heated to redness.

† Reuss, de Sale Sedat. 1778.

‡ Kirwan's Min. ii. 4.

§ Hassenfratz, Ann. de Chim. xxviii. 11.

|| Elements of Chemical Philosophy, p. 213.

It is very sparingly soluble in water. Boiling water scarcely dissolves 0·02 of boracic acid, and cold water a still smaller quantity. When this solution is distilled in close vessels, part of the acid evaporates along with the water, and crystallizes in the receiver. Water, therefore, renders it in some measure volatile, though it is perfectly fixed when in a state of dryness.

It is soluble in alcohol; and alcohol containing it burns with a green flame. Paper dipped into a solution of boracic acid burns with a green flame.

With the assistance of a distilling heat, it dissolves in oils, especially in mineral oils; and with these it yields fluid and solid products, which give a green colour to spirit of wine.

II. None of the simple supporters of combustion has any action on boracic acid so far as is known.

III. Of the simple combustibles potassium and sodium alone are capable of decomposing it, as far as the experiment has hitherto been made.

Hydrogen gas produces no effect upon it whatever, though mixed with fine powder of charcoal; it is nevertheless capable of vitrification; and with soot it melts into a black bitumen-like mass, which is, however, soluble in water, and cannot be easily calcined to ashes, but sublimes in part.*

When boracic acid is rubbed with phosphorus, it does not prevent its inflammation; but an earthy yellow matter is left behind.†

It is hardly capable of oxidizing or dissolving any of the metals except iron and zinc, and perhaps copper.

Boracic acid combines with alkalies, alkaline earths, and alumina, and most of the metallic oxides, and forms compounds which are called *borates*.

SECT. V.

OF SILICA.

This substance was long arranged among the *earths proper*, though it was very different from these bodies in its properties; being incapable of uniting with acids; but occurring in great abundance united to alkaline bodies and earths. Mr. Smithson first suggested that it possessed the characters of an acid, and this opinion has been very ingeniously confirmed by

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* Keir's Dictionary.

† Ibid.

Berzelius. It might therefore be distinguished by the name of *silicic acid*, which would be more systematic than the term *silica*, which was applied to it when it was considered as an earth. I shall not attempt, however, to make use of the new name here; though I have no doubt that it will gradually come into general use.

Preparation.

1. Silica may be obtained pure by the following process: Mix together, in a crucible, 1 part of pounded flint or quartz, and 3 parts of potash, and apply a heat sufficient to melt the mixture completely. Dissolve the mass formed in water, saturate the potash with muriatic acid, and evaporate to dryness. Towards the end of the evaporation the liquid assumes the form of a jelly: and when all the moisture is evaporated, a white mass remains behind. This mass is to be washed in a large quantity of water, and dried; it is then silica in a state of purity.

Properties.

2. Silica, thus obtained, is a fine white powder, without either taste or smell. Its particles have a harsh feel, as if they consisted of very minute grains of sand. Its specific gravity is 2·66.*

It may be subjected to a very violent heat without undergoing any change. Lavoisier and Morveau exposed it to the action of a fire maintained by oxygen gas without any alteration.† Saussure indeed has succeeded in fusing, by means of the blowpipe, a portion of it so extremely minute as scarcely to be perceptible without a glass. According to the calculation of this philosopher, the temperature necessary for producing this effect is equal to 4043° Wedgewood.

Action of water.

3. It is insoluble in water except when newly precipitated, and then 1 part of it is soluble in 1000 parts of water.‡ It has no effect on vegetable colours.

It is capable of absorbing about one fourth of its weight of water, without letting any drop from it; but on exposure to the air, the water evaporates very readily.§ When precipitated from potash by means of muriatic acid and slow evaporation, it retains a considerable portion of water, and forms with it a transparent jelly; but the moisture gradually evaporates on exposure to the air.

I find that when gelatinous silica is dried in a temperature of 112°, it still continues very nearly a hydrate composed of 1 atom silica, and 2 atoms water. For 67·8 grains of it dried

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* Kirwan's Min. i. 10.

† Jour. de l'Ecole Polytech. I. iii. 299.

‡ Kirwan's Min. i. 10.

§ Ibid.

in this temperature on exposure to a strong red heat lose 34·2 grains of water. Hence the hydrate was composed of

Silica	33·6
Water	34·2
	67·8

If we consider the weight of an integrant particle of silica to be 2, then the hydrate, considering it a compound of 1 atom silica, and 2 atoms water, would consist of

Silica	31·9	or	33·6
Water	35·9		37·81
	67·8		

Now this differs from the experimental result but little. Probably had the silica been merely dried in the open air, without any artificial heat, it would have been an exact compound of 1 atom silica and 2 atoms water.

Silica may be formed into a paste with a small quantity of water; this paste has not the smallest ductility, and when dried forms a loose, friable, and incoherent mass.*

Crystals.

Silica is capable of assuming a crystalline form. Crystals of it are found in many parts of the world. They are known by the name of *rock crystal.* When pure they are transparent and colourless like glass: they assume various forms; the primitive form is a rhomboid differing but little from a cube; but the most usual is a hexagonal prism, surmounted with hexagonal pyramids on one or both ends, the angles of the prism corresponding with those of the pyramids. Their hardness is very great, amounting to 11. Their specific gravity is 2·653.†

There are two methods of imitating these crystals by art. The first method was discovered by Bergman. He dissolved silica in fluoric acid, and allowed the solution to remain undisturbed for two years. A number of crystals were then found at the bottom of the vessel, mostly of irregular figures, but some of them cubes with their angles truncated. They were hard, but not to be compared in this respect with rock crystal.‡

The other method was discovered by accident. Professor Seigling of Erfurt had prepared a liquor silicum, which was more than usually diluted with water, and contained a superabundance of alkali. It lay undisturbed for eight years in a glass vessel, the mouth of which was only covered with paper.

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* Scheele.

† Kirwan's Min. i. 242.

‡ Bergman, ii. 32.

Happening to look to it by accident, he observed it to contain a number of crystals; on which he sent it to Mr. Trommsdorf, Professor of Chemistry at Erfurt, who examined it. The liquor remaining amounted to about two ounces. Its surface was covered by a transparent crust, so strong that the vessel might be inverted without spilling any of the liquid. At the bottom of the vessel were a number of crystals, which proved on examination to be sulphate of potash and carbonate of potash.* The crust on the top consisted partly of carbonate of potash, partly of crystallized silica. These last crystals had assumed the form of tetrahedral pyramids in groupes; they were perfectly transparent, and so hard that they struck fire with steel.†

II. None of the simple supporters, so far as is known, are capable of acting upon silica.

III. It is probable that potassium and sodium are capable of decomposing silica when assisted by heat; but none of the other simple combustibles produce any effect upon it whatever.

Union with alkalies.

IV. Silica dissolves readily in fixed alkaline leys, and when the alkali is saturated with an acid and the solution is evaporated, the silica separates in the form of a jelly. When this jelly is dried, it becomes a white powder. When this white powder is mixed with pure fluoric acid, it disappears, and the acid is immediately converted into a gas. But none of the other acids are capable of dissolving silica. It may indeed be fused into a glass with phosphoric or boracic acid.

When the potash exceeds the silica considerably, the compound is soluble in water, and constitutes what was formerly called *liquor silicum*, and now sometimes *silicated potash* or *soda*. When the silica exceeds, the compound is transparent and colourless like rock crystal, and is neither acted on by water, air, nor (excepting one) by acids. This is the substance so well known under the name of *glass*.

Silica is not acted on by ammonia, whether in the gaseous or liquid state.

With barytes.

There is a strong affinity between barytes and silica. When barytes water is poured into a solution of silica in potash, a precipitate appears, which may be considered as the two earths in a state of combination.‡ Barytes and silica may be combined by means of heat. The compound is of a greenish co-

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* Potash combined with sulphuric acid and carbonic acid.

† Nicholson's Journal, i. 217.

‡ Morveau, Ann. de Chim. xxxi. 250.

lour, and coheres but imperfectly.* The effect of heat on various mixtures of barytes and silica will appear from the following experiments of Mr. Kirwan.†

Proportions.	Heat.	Effect.
80 Silica 20 Barytes	150° Wedg.	A white brittle mass.
75 Silica 25 Barytes	150	A brittle hard mass, semitransparent at the edges.
66 Silica 33 Barytes	150	Melted into a hard, somewhat porous porcelain mass.
50 Silica 50 Barytes	148	A hard mass not melted.
20 Silica 80 Barytes	148	The edges were melted into a pale greenish matter between a porcelain and enamel.
25 Silica 75 Barytes	150	Melted into a somewhat porous porcelain mass.
33 Silica 66 Barytes	150	Melted into a yellowish and partly greenish white porous porcelain.

When the barytes is two or three times the quantity of the silica, the fused mass is soluble in acids.

Strontian, Strontian and silica combine with each other nearly in the same manner.

Lime, There is also an affinity between silica and lime. When lime water is poured into a solution of silica in potash, a precipitate appears, as Stucke discovered. This precipitate is a compound of silica and lime.‡ These two earths may be combined also by means of heat. They form a glass, provided the quantity of lime be not inferior to that of silica. The effect of heat upon these earths, mixed in various proportions, will appear from the following experiments of Mr. Kirwan.§

Proportions.	Heat.	Effect.
50 Lime 50 Silica	150° Wedg.	Melted into a mass of a white colour, semitransparent at the edges, and striking fire, though feebly, with steel: it was somewhat between porcelain and enamel.

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* Vauquelin, Ann. de Chim. xxix. 271.

† Kirwan's Miner. i. 57.

‡ Gadolin, Ann. de Chim. xxii. 110.—Morveau, ibid. xxxi. 250.

§ Kirwan's Min. i. 56.

Proportions.	Heat.	Effect.
80 Lime 20 Silica	156° Wedg.	A yellowish white loose powder.
20 Lime 80 Silica	156	Not melted, formed a brittle mass.

Magnesia,

Equal parts of magnesia and silica melt with great difficulty into a white enamel when exposed to the most violent heat which can be produced.* They are infusible in inferior heats in whatever proportion they are mixed.†

And alumina.

There is a strong affinity between alumina and silica. When equal portions of silicated and aluminated potash are mixed together, a brown zone immediately appears, which may be made, by agitation, to pass through the whole liquid. After standing about an hour, the mixture assumes the consistence of jelly.‡ When formed into a paste with water, and dried, they cohere, and contract a considerable degree of hardness. When baked in the temperature of 160° Wedgewood, they become very hard, but do not fuse.§ Achard found them infusible in all proportions in a heat probably little inferior to 150° Wedgewood. But when exposed to a very strong heat, they are converted into a kind of opaque glass, or rather enamel. Porcelain, stoneware, brick, tiles, and other similar substances, are composed chiefly of this compound. Mixtures of silica and alumina in various proportions constitute *clays;* but these are seldom uncontaminated with some other ingredients.

It follows from the experiments of Achard, that equal parts of lime, magnesia, and silica, may be melted into a greenish coloured glass, hard enough to strike fire with steel; that when the magnesia exceeds either of the other two, the mixture will not melt; that when the silica exceeds, the mixture seldom melts, only indeed with him in the following proportions; three silica, two lime, one magnesia, which formed a porcelain: and that when the lime exceeds, the mixture is generally fusible.||

A mixture of silica and alumina may also be combined with barytes or strontian by means of heat. The mixture melts readily into a greenish coloured porcelain.**

From the experiments of Achard and Kirwan, we learn, that in mixtures of lime, silica, and alumina, when the lime

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* Lavoisier, Mem. Par. 1787, p. 598.

† Achard, Mem. Berl. 1780, p. 33.

‡ Morveau, Ann. de Chim. xxxi. 249.

§ Kirwan's Min. i. 58.

|| Mem. Berl. 1780, p. 33, and Jour. de Phys. xxiv.

** Kirwan.

exceeds, the mixture is generally fusible either into a glass or porcelain, according to the proportions. The only infusible proportions were,

2	3	Lime
1	1	Silica
2	2	Alumina.

That if the silica exceeds, the mixture is frequently fusible into an enamel or porcelain, and perhaps a glass; and that when the alumina exceeds, a porcelain may often be attained, but not a glass.*

As to mixtures of magnesia, silica, and alumina, when the magnesia exceeds, no fusion takes place at 150°. When the silica exceeds, a porcelain may often be attained; and 3 parts silica, 2 magnesia, and 1 alumina form a glass. When the alumina exceeds, nothing more than a porcelain can be produced.†

Achard found that equal parts of lime, magnesia, silica, and alumina, melted into a glass. They fused also in various other proportions, especially when the silica predominated.

Weight of an atom of silica.

There can be little doubt that in these cases there is a chemical combination formed between the silica and the earth, in which the former acts the part of an acid and the latter that of an alkaline body. But it is not easy to determine the proportions in which these bodies saturate each other, as there are no phenomena which indicate the point of saturation. Perhaps the safest method will be to have recourse to compounds ready formed by nature, which from their crystallized state may be considered as neutral *silicates*. I shall select two examples, which will be sufficient to show that the number 2 fixed upon formerly for the weight of an atom of silica was not taken up at random.

There is a mineral called *sommite* or *nepheline*, usually found in volcanic productions crystallized in regular six sided prisms. Its constituents, according to Vauquelin, are 49 alumina + 46 silica. Now 49 : 46 :: 2·125 : 1·994. So that if it be a compound of 1 atom silica + 1 atom alumina, an atom of silica will weigh 1·994. There is another mineral called *schalstone* or *tablespar*, which has been hitherto found only in the Bannat of Tameswar, it is foliated and translucent; and according to Klaproth's analysis is composed of 50 silica + 45 lime. Now 45 : 50 :: 3·625 : 4·03. So that if schalstone

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* Kirwan's Min. i. 73.

† Ibid. 72.

be a bisilicate of lime, or a compound of 2 atoms silica and 1 atom lime, then the weight of an atom of silica will be 2·015. Now the mean of 1·994 and 2·015 is 2·0045. So that these two minerals give us 2 as the weight of an atom of silica.

SECT. VI.

OF PHOSPHORIC ACID.

Preparation.

The most economical way of preparing phosphoric acid is to allow the phosphorus to run slowly into an acid liquor by spontaneous combustion in the atmosphere. The liquor thus obtained must be mixed with nitric acid, and after being digested for some time it must be evaporated to dryness in order to get rid of the excess of nitric acid which it contains. The dry residue is phosphoric acid combined with a portion of water in a state of hydrate.

Properties.

Phosphoric acid thus obtained has the aspect of glass. Sometimes it is quite transparent; but most usually is to a certain degree milky. It reddens vegetable blues; it has no smell, its taste is very acid, but it does not destroy the texture of organic bodies.

When exposed to the open air, it soon attracts moisture, and deliquesces into a thick oily-like liquid; in which state it is usually kept by chemists. When exposed to fire in a platinum crucible, its water gradually evaporates, and leaves it in the state of a transparent jelly. If the heat be increased it boils and bubbles up, owing to the separation of the remainder of its water, accompanied with a small portion of acid. At a red heat it assumes the form of a transparent liquid, and when cooled resembles the purest crystal. In this state it is known by the name of *phosphoric glass*. This glass is merely phosphoric acid deprived of a portion of its water. It has an acid taste, is soluble in water, and deliquesces when exposed to the air. At a red heat it evaporates in a white smoke, unless the evaporation be prevented by the presence of a base.

The specific gravity of this acid, in a state of dryness, is 2·687;* in the state of glass, 2·8516;† in the state of deliquescence, 1·417.‡

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* Bergman's Sciographia, p. 90. Eng. Trans.

† Hassenfratz, Ann. de Chim. xxviii. 11.

‡ Encyc. Method. Chim. i. 221.

Action of water.

3. This acid is very soluble in water. When in the state of white flakes, it dissolves with a hissing noise, similar to that made by red-hot iron plunged into water. When in the state of glass, it dissolves much more slowly. The heat evolved during the combination of this acid and water is much inferior to that evolved when sulphuric acid enters into a similar combination. Phosphoric acid obtained by deliquescence, when mixed with an equal quantity of distilled water, acquired so little heat as to raise the thermometer only one degree, as Mr. Sage observed. M. Lavoisier raised the thermometer from 50° to 63° by mixing phosphoric acid, boiled to the consistence of a syrup, with an equal quantity of water; and from 50° to 104° when the acid was as thick as turpentine.*

II. The simple supporters of combustion have no action on this acid, so far as is known.

Of combustibles.

III. Of the simple acidifiable combustibles, the effect of hydrogen has not been tried. From theory it ought to decompose the acid, and produce phosphuretted hydrogen and water. Charcoal decomposes phosphoric acid. The effect of boron and silicon has not been tried. Probably phosphorus, sulphur, arsenic, and tellurium, have no sensible action.

Of metals.

Potassium and sodium decompose this acid with facility; and a few of the other metals have been ascertained to produce similar effects. This acid, when in a liquid state, is capable of oxidizing some of the metals, especially when assisted by heat; at the same time hydrogen gas is emitted. Hence we see that the oxidizement is owing to the decomposition of water. In this manner it oxidizes iron, tin, lead, zinc, antimony, bismuth, manganese; but on some of these it acts very slowly. When fused with several of these metals, as tin, iron, and zinc, it is converted into phosphorus; a proof that they have a stronger affinity for oxygen.

It does not act upon gold, platinum, silver, copper, mercury, arsenic, cobalt, nickel. It appears, however, to have some action on gold in the dry way, as it is called; for when fused with gold-leaf it assumes a purple colour: a proof that the gold has been oxidized.

IV. From the facts stated in a former part of this work, there seems no reason to doubt that this acid is a compound of 1 atom phosphorus + 2 atoms oxygen, or of

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* Keir's Dictionary.

Phosphorus	1·5	100
Oxygen	2·0	133⅓

Hence the weight of an integrant particle of it must be 3·5. This does not agree with the analysis of the phosphates hitherto made by Berzelius. From his experiments it follows that the equivalent number for phosphoric acid is 4·5. But as this number does not tally with his own experimental determination of the composition of phosphoric acid, we cannot hesitate to conclude that he has fallen into some mistake in his analysis of the phosphates.

SECT. VII.

OF PHOSPHOROUS ACID.

Preparation.

This acid was first examined in a state of purity by Sir H. Davy. It may be obtained by the following process. Sublime phosphorus through corrosive sublimate in powder in a glass tube. A colourless liquid comes over, which must be mixed with water and evaporated to the consistence of a syrup. In this state it is a combination of phosphorous acid and water. On cooling it becomes solid, has an acid taste, reddens vegetable blues, and possesses all the characters of a strong acid. When heated strongly in open vessels it catches fire, emitting abundance of phosphuretted hydrogen gas; the residue is phosphoric acid. Sir H. Davy ascertained that ten parts of it when heated in close vessels left 8·5 parts of phosphoric acid, and gave off 1·5 parts of bihydroguret of phosphorus.* According to this experiment the hydrate of phosphorous acid is a compound of

Phosphorous acid	80·74	100
Water	19·26	23·85

This approaches most nearly to a compound of three atoms phosphorous acid and two atoms water. This would give us its composition as follows:

Phosphorous acid	100
Water	21·47

Probably its real composition is 1 atom acid + 1 atom water, which would give us

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* Phil. Trans. 1812, p. 408.

Acid	100
Water	32

II. No experiments have been hitherto published respecting the action of the simple supporters and combustibles on this acid.

Composition. III. A careful analysis of what takes place when chloride of phosphorus is converted into phosphorous and muriatic acids is sufficient to demonstrate that phosphorous acid is a compound of 1 atom phosphorus + 1 atom oxygen, or of

Phosphorus	1·5	100
Oxygen	1·0	$66\frac{2}{3}$

Dulong has made a set of experiments on the acid formed by the slow combustion of phosphorus, which used to be considered as *phosphorous acid.* He has found it always a compound of exactly the same proportions of phosphoric and phosphorous acid. Hence he considers it as a compound of the two in a state of chemical union. On that account he has distinguished it by the name of *phosphatic* acid. But neither his analysis, nor that of Thenard, seem entitled to much confidence.*

SECT. VIII.

ON HYPOPHOSPHOROUS ACID.

Discovery. THIS acid has been recently discovered by M. Dulong, and has been but imperfectly examined. It is probable that the snow-white matter which sublimes when phosphorus is exposed to heat in a narrow glass tube, and which burns spontaneously when it comes in contact with the atmosphere, is this acid. It has a sour taste, and dissolves with facility in hot water. But the method taken by Dulong to procure it was the following:

Preparation. Phosphuret of barytes is allowed to remain in water till it has given out all the phosphuretted hydrogen gas which it is capable of forming. The liquid is then filtered to separate the insoluble phosphates. It holds, in solution, a combination of hypophosphorous acid and barytes. Let the barytes be separated by the cautious addition of sulphuric acid, and the pre-

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* Thenard found it a compound of 100 phosphorus + 110·4 oxygen; Dulong of 100 phosphorus + 109 oxygen.

cipitate removed by filtration. The liquid now contains nothing but a solution of hypophosphorous acid in water.*

When sufficiently concentrated by evaporation, this acid assumes the form of a viscid liquid, which has a very sour taste, reddens vegetable blues, and does not crystallize. When the heat is raised higher the acid is decomposed, phosphuretted hydrogen is emitted, a little phosphorus sublimes, and phosphoric acid remains behind. It absorbs oxygen from the atmosphere, and even from other bodies, with considerable energy. Dulong attempted to analyze this acid by converting a given quantity of it into phosphoric acid by means of chlorine. He concluded, from his experiments, that it is a compound of

Phosphorus	100
Oxygen	37·44

But his analysis is not of a nature to inspire much confidence in its accuracy.

Composition.

Were we to consider it as a compound of 2 atoms phosphorus + 1 atom oxygen, it would consist of

Phosphorus	3 or	100
Oxygen	1 ..	$33\frac{1}{3}$

Numbers which approach tolerably near the result of the analysis of Dulong. But it has not been ascertained that hydrogen does not enter as a constituent into the composition of this acid.

II. The action of the supporters and the combustible upon this acid still continues unknown.

Hypophosphites.

III. The salts which it forms, by uniting with the salifiable bases, are called *hypophosphites*. They possess the remarkable property of being all very soluble in water. In this respect they agree with the *nitrates* and *acetates*, which possess the same property. The *phosphites* and *phosphates*, on the other hand, are many of them insoluble.

SECT. IX.

OF SULPHURIC ACID.

Preparation.

There are two ways of obtaining this acid. The first, which has been long employed at Nordhausen in Germany,

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* Ann. de Chim. et de Phys. ii. 141.

furnishes a black-coloured fuming acid, of a considerably greater specific gravity than the sulphuric acid which is manufactured in this country. The method employed at Nordhausen is to distil green vitriol previously deprived of its water of crystallization. The sulphuric acid is disengaged from the oxide of iron by the heat, and it owes its fuming qualities, and greater specific gravity, to the small quantity of water with which it is united.

The method of manufacturing sulphuric acid in this country is to burn a mixture of 1 part of nitre and about 7 parts of sulphur in large chambers lined with lead, and having their bottoms covered with water. By this combustion the sulphur is converted into sulphurous acid gas, while the nitre, at the same time, emits a quantity of nitrous gas, which, uniting with the oxygen of the atmosphere, is immediately converted into nitrous acid. The nitrous and sulphurous acids unite, and lose in consequence their gaseous form. But the moment they come in contact with the water in the bottom of the chamber, their union is dissolved. The sulphurous acid is converted into sulphuric acid at the expense of the nitrous acid, which being deprived of the oxygen which it had taken from the atmosphere, makes its escape again in the form of nitrous gas. It is again converted into nitrous acid, again combines with sulphurous acid, and is again disengaged when it comes in contact with the water. These successive combinations and decompositions go on till the whole of the sulphurous acid is converted into sulphuric acid.* When the water at the bottom of the chamber has imbibed a certain quantity of sulphuric acid it is concentrated, by evaporation, in leaden vessels. When it has become so strong as to be able to act upon leaden vessels at a boiling heat, it is put into glass retorts, and the concentration continued till the specific gravity of the acid is about 1·85 or 1·84. In this state it occurs in commerce.

It is to Dr. Roebuck that we are indebted for the first introduction of the method of preparing sulphuric acid in leaden chambers. It immediately reduced the price of sulphuric acid in Great Britain to one fourth of its former price. It was

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* For this very ingenious and satisfactory explanation we are indebted to Clement and Desormes, and to Sir H. Davy, who completed it. See Ann. de Chim. lix. 329. See likewise Dalton's New System of Chemical Philosophy, ii. 396; and Davy's Elements, p. 277.

introduced, in consequence, into the art of bleaching, as a substitute for sour milk; and was the first great improvement which that art received from modern chemistry. The sulphuric acid of commerce always contains a minute quantity of sulphate of lead and sulphate of potash derived from the leaden chamber, and the nitre used in its preparation. But it is easily freed from these impurities by distillation over the naked fire in a glass retort.

When the fuming acid of Nordhausen is put into a glass retort, and distilled by a moderate heat (the receiver being surrounded with ice), the fuming portion comes over first, and may be obtained in a separate state by stopping the distillation in time. Thus obtained, it constitutes *sulphuric acid* in a state of absolute purity.

Properties.

1. In this state it is solid, and appears as if it were composed of silky filaments. It is tough and difficult to cut, and bears considerable resemblance to the mineral called asbestos. When exposed to the air, it fumes strongly, and gradually flies off in vapour. It may be held for some time between the fingers without any sensible action on the skin; but, after a certain time, a sensation of pain is perceived in the interior of the fingers. It remains solid at a temperature at least as high as 66°; but when the heat is increased, it assumes the form of a colourless vapour, which becomes white when it comes in contact with moist air.

2. It has not been possible to determine the specific gravity of this solid acid, because it acts upon every liquid with which it comes in contact. The specific gravity of the vapour has not been determined. But it must be a compound of 100 volumes of sulphurous acid gas and 50 volumes of oxygen gas reduced into 100 volumes. Hence its specific gravity ought to be 2·777, that of common air being considered as 1.

3. When dropped into water, it combines with that liquid so violently as to make a noise similar to that made by a red-hot bar of iron when dipped into water. When the quantity of acid is considerable, a kind of explosion takes place, owing to the suddenness with which a great deal of heat is evolved; but nothing is extricated except water in the state of vapour. When united with about one-fifth part of its weight of water, it is converted into the common concentrated sulphuric acid of commerce, which is a hydrate of sulphuric acid.

4. From the experiments of Vogel, it appears that absolute sulphuric acid is capable of dissolving sulphur, and of assum-

ing a blue, green, or brown colour, according to the proportion of sulphur held in solution. Phosphorus decomposes it, and absorbs its oxygen with such impetuosity as to take fire.*

5. The specific gravity of the fuming sulphuric acid of Nordhausen is 1·896. It is, I conceive, a compound of 2 atoms acid with 1 atom water, or of

Sulphuric acid....	10	 100
Water	1·125	.... 11·25

When heated, one of the atoms of sulphuric acid makes its escape. The remainder continues united to the atom of water constituting the common hydrate, or the most concentrated acid that can be obtained by the combustion of sulphur and nitre.

Liquid acid.

6. The concentrated acid of this country is a transparent liquid, like water, and having somewhat of an oily consistency. Hence the old name of *oil of vitriol,* by which it was distinguished. Its taste is intensely acid. It reddens vegetable blues, and speedily chars those animal and vegetable substances to which it is applied, especially if its action be assisted by heat.

7. Its specific gravity, and its boiling point vary according to the proportion of water which it contains. The following very valuable table, drawn up by Mr. Dalton, from his own experiments, exhibits a satisfactory view of both of these variations.†

Table of its strength and boiling points.

Atoms. Acid. Water.	Acid per cent. by weight	Acid per cent. by measure.	Specific gravity.	Boiling point.
1 + 1	81	150	1·850	620°
	80	148	1·849	605
	79	146	1·848	590
	78	144	1·847	575
	77	142	1·845	560
	76	140	1·842	545
	75	138	1·838	530
	74	135	1·833	515
	73	133	1·827	501
	72	131	1·819	487
	71	129	1·810	473

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* Vogel. Schweigger's Journal, iv. 121.

† New System of Chemical Philosophy, ii. 404.

TABLE—*continued.*

Atoms. Acid. Water.	Acid per cent. by weight.	Acid per cent. by measure.	Specific gravity.	Boiling point.
1 + 1	70	126	1·801	460
	69	124	1·791	447
1 + 2	68	121	1·780	435
	67	118	1·769	422
	66	116	1·757	410
	65	113	1·744	400
	64	111	1·730	391
	63	108	1·715	382
	62	105	1·699	374
	61	103	1·684	367
	60	100	1·670	360
1 + 3	58·6	97	1·650	350
	50	76	1·520	290
	40	56	1·408	260
1 + 10	30	39	1·30+	240
1 + 17	20	24	1·200	224
1 + 38	10	11	1·10−	218

Various statements are to be met with in books of the specific gravity of the sulphuric acid of this country which is a compound of 1 atom acid + 1 atom water. From my own experiments, I conclude that when quite pure its specific gravity is 1·8447. In commerce it often occurs as high as 1·85 or 1·86. But such acid is always contaminated with some salt or other; most commonly with sulphate of lead.

Congelation.

8. When exposed to a sufficient degree of cold, it crystallizes or freezes; and after this has once taken place, it freezes again by the application of a much inferior cold.* Morveau froze it at − 4°; it assumed the appearance of frozen snow. After the process began, it went on in a cold not nearly so intense. The acid melted slowly at 27·5°; but it froze again at the same temperature, and took five days to melt in the temperature of 43°.† Chaptal, who manufactured this acid, once observed a large glass vessel full of it crystallized at the temperature of 48°. These crystals were in groups, and consisted of flat hexahedral prisms, terminated by a six-sided pyramid.

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[*] The freezing point was ascertained by the Duc d'Ayen in 1776. See Macquer's Dictionary.

[†] Encycl. Method. Chim. i. 376.

They felt hotter than the surrounding bodies, and melted on being handled.* Chaptal has observed, that sulphuric acid, in order to crystallize, must not be too concentrated. This observation has been extended a good deal further by Mr. Kier. He found that sulphuric acid, of the specific gravity of 1·780, froze at 45°; but if it was either much more or much less concentrated, it required a much greater cold for congelation.† When as concentrated as possible, I find that it may be cooled down in thermometer tubes to the temperature of — 36° before it congeals.‡

Action of water.

9. Sulphuric acid has a very strong attraction for water. Neuman found, that when exposed to the atmosphere it attracted 6·25 times its own weight. Mr. Gould found, that 180 grains of acid, when exposed to the atmosphere, attracted 68 grains of water the first day, 58 the second, 39 the third, 23 the fourth, 18 the fifth, and at last only 5, 4, 3, 4, 3, &c. The 28th day the augmentation was only half a grain.§ The affinity, therefore, between sulphuric acid and water, as is the case in general with other substances, becomes weaker the nearer it approaches to saturation.

II. None of the simple supporters, so far as we know, are capable of acting on sulphuric acid.

III. Many of the simple combustibles decompose it when assisted by heat.

Of combustibles.

1. When hydrogen gas and sulphuric acid are made to pass together through a red-hot tube of porcelain, the acid is completely decomposed, water is formed, and sulphur deposited.‖

2. At the boiling temperature charcoal also absorbs oxygen from it, and converts it into sulphurous acid. At a red heat it even converts it into sulphur.

3. Boron and silicon would likewise decompose it, but the experiment has not been tried.

4. Phosphorus absorbs oxygen from it by the assistance of heat, sulphurous acid is driven off, and phosphoric acid formed.

5. When sulphur is boiled in this acid, it absorbs a portion of its oxygen, or at least combines with it, and the whole is converted into *sulphurous* acid.

Of metals.

6. When zinc or iron is thrown into sulphuric acid, a vio

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* Jour. de Phys. xxxi. 473.

† Phil. Trans. lxxvii. Part. ii.

‡ See vol. i. p. 50, for the law of its congelation.

§ Phil. Trans. 1684.

‖ Fourcroy, ii. 62.

lent action takes place, if the acid be diluted; water is decomposed, its hydrogen flies off, and its oxygen combines with the metals. If the acid be concentrated, the action is much less violent, and sulphurous acid exhales. Upon tin and copper the acid acts very slowly and feebly, unless its action be assisted by heat, when it oxidizes and dissolves them. On silver, mercury, antimony, bismuth, arsenic, and tellurium, it does not act except at a pretty high temperature. These metals abstract part of its oxygen, and convert one portion of it to sulphurous acid, while another portion combines with the oxides thus formed. When boiling-hot it oxidizes lead, and dissolves cobalt, nickel, and molybdenum: but it has no perceptible action on gold nor platinum at any temperature to which it can be raised.

Of alkalies and earths.

IV. It unites readily with all the alkalies and earths, and with most of the metallic oxides, and forms salts denominated *sulphates*. Thus the combination of sulphuric acid and soda is called *sulphate of soda;* the compound of sulphuric acid and lime, *sulphate of lime*, and so on.

Composition.

V. It has been already shown in a preceding part of this work that sulphuric acid is a compound of 1 atom sulphur, and 3 atoms oxygen, or by weight of

Sulphur	2	100
Oxygen	3	150

SECT. X.

OF SULPHUROUS ACID.

Preparation.

THIS acid is easily obtained by the following process. Put into a small retort a mixture of 2 parts mercury and 1 part sulphuric acid by weight. Apply the heat of a lamp. An effervescence speedily takes place, and a gas comes over, which may be received in glass jars filled with mercury, and standing in the mercurial trough. This gas is sulphurous acid.

Properties.

1. Sulphurous acid, in the state of gas, is colourless and invisible like common air. It is incapable of maintaining combustion: nor can animals breathe it without death. It has a strong and suffocating odour, precisely the same with that exhaled by sulphur burning with a blue flame: sulphur, by such a combustion, being totally converted into sulphurous acid. Its specific gravity is 2·222, that of air being 1·000.

2. This acid reddens vegetable blues, and gradually destroys the greater number of them. It exercises this power on a great variety of vegetable and animal colours. Hence the use of the fumes of sulphur in bleaching wool and in whitening linen stained by means of fruits.

Planche has observed, that when syrup of violets, previously reddened by acids, is mixed with a little sulphurous acid, the original blue colour of the syrup is restored, and its intensity gradually diminishes.[*]

3. Dr. Priestley discovered, that when a strong heat is applied to this acid in close vessels, a quantity of sulphur is precipitated, and the acid is converted into sulphuric.[†] Berthollet obtained the same result; but Fourcroy and Vauquelin could not succeed.[‡]

According to Clouet and Monge, when this gas, in a state of condensation, is exposed to the temperature of − 18°, it is condensed into a liquid.[§]

Action of water.

4. Water absorbs this acid with rapidity. According to Dr. Priestley, 1000 grains of water, at the temperature 54·5°, absorb 39·6 grains of this acid. Fourcroy, on the other hand, affirms, that water at 40° absorbs the third of its weight of sulphurous acid gas.[‖] Upon trying the experiment, I found that one cubic inch of water at the temperature of 61°, barometer 29·55 inches, absorbs 33 inches of gas. But an inch of water weighs about 253·175 grains, and 33 inches of gas weigh 23·16. Hence it follows, that 1000 water in weight absorbs 91·5 of this gas. This exceeds considerably the estimate of Priestley, though it comes short of that of Fourcroy. Water impregnated with this gas acquires, according to my experiments, the specific gravity 1·0513, even in as high a temperature as 68°. This water may be frozen without parting with any of the acid gas. When water, which has been saturated with this acid at the freezing temperature, is exposed to the heat of 65·25°, it is filled with a vast number of bubbles, which continually increase and rise to the surface. These bubbles are a part of the acid separating from it. It freezes a few degrees below 22°.[**]

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[*] Ann. de Chim. lx. 253.

[†] On Air, ii. 330.

[‡] Nicholson's Journal, i. 513.

[§] Fourcroy, ii. 74.

[‖] Fourcroy, p. 77.

[**] Fourcroy and Vauquelin, Nicholson's Jour. i. 513.

II. Of the simple supporters the action of oxygen only on this gas has been examined with minute attention.

Oxygen gas and sulphurous acid gas do not combine at the common temperature of the air if they are kept dry. But if water be present they gradually combine, and are converted into sulphuric acid. When passed through a red hot tube, or when electrical sparks are passed through the mixture, they combine likewise and constitute sulphuric acid.

Action of combustibles

III. The action of the simple acidifiable combustibles on this gas has not been examined with much care.

According to the experiments of Fourcroy and Vauquelin, when hydrogen or charcoal is made to act upon the gas at a red heat it is decomposed, water or carbonic acid being formed and sulphur deposited. The action of boron and silicon has not been tried. Phosphorus and sulphur seem to be incapable of decomposing it.

It is readily decomposed by potassium and sodium. It dissolves iron without the evolution of any gas, as was first observed by Mr. Higgins.[*] When exposed to the action of peroxide of lead it is absorbed as Berzelius first ascertained, and the peroxide converted into common sulphate of lead.[†] Peroxide of manganese produces a similar change in this acid. The action of the remaining metals and their oxides on this acid gas is still imperfectly known.

Triple acid.

IV. When nitromuriatic acid is left for a long time in contact with sulphuret of carbon, that substance is converted into a crystallized body insoluble in water, but soluble in alcohol and ether, having an acid taste, and very much resembling camphor in its properties. According to the analysis of Berzelius this substance is a triple compound of muriatic acid, sulphurous acid, and carbonic acid, in the following proportions:

Muriatic acid ……	48·74	or 2 atoms
Sulphurous acid ..	29·63	1
Carbonic acid ….	21·63	1
	100·00	

But the nature of this problematical substance would still require farther elucidation.[‡]

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[*] Higgins' Comparative View, p. 19.

[†] Phil. Trans. 1813, p. 186.

[‡] Ibid. p. 195, and Annals of Philosophy, iii. 189.

Composition.

V. From the experiments of Sir H. Davy it seems to follow very clearly that oxygen gas may be converted into sulphurous acid gas without any change of bulk.* Hence it follows that it is a compound of 1 volume of oxygen + 1 volume of sulphur vapour condensed into 1 volume. Sulphuric acid vapour on the other hand is a compound of $1\frac{1}{2}$ volume of oxygen + 1 volume sulphur vapour condensed into 1 volume. Hence their specific gravities are as follows:

Sulphurous acid gas	2·222
Sulphuric acid vapour	2·777

Their constituents are

	Sulphur.		Oxygen.		Sulphur.		Oxygen.
Sulphurous acid ..	1 atom	+	2 atoms	or	100	+	100
Sulphuric acid	1	+	3		100	+	150

VI. Sulphurous acid combines with the salifiable bases, and constitutes a genus of salts known by the name of *sulphites.*

SECT. XI.

OF HYPOSULPHUROUS ACID.

Preparation.

When sulphuret of lime is dissolved in water we obtain a greenish yellow coloured solution having the smell of sulphuretted hydrogen gas, and precipitating all the metal from their solutions. If this liquid be preserved for some time, it gradually becomes colourless and loses its peculiar smell. If it be now evaporated it yields large crystals, most commonly in the state of six-sided prisms, and having an exceedingly bitter taste. They consist of hyposulphurous acid and lime united together in the proportion, according to Mr. Herschell's analysis, of 2 atoms acid to 1 atom lime, and united to 6 atoms water.† Hence the constituents of the salt must be

Hyposulphurous acid	6·000	or	36·64
Lime	3·625		22·14
Water	6·750		41·22
	16·375		100·00

From this salt, which is easily procured by passing a current of sulphurous acid gas through hydroguretted sulphuret

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* Elements of Chemical Philosophy, p. 273.

† Edinburgh, Phil. Journal, i. 15.

of lime, the other hyposulphites may be readily obtained. These salts are colourless, and, with an exception or two, they are soluble in water. Their taste is most commonly bitter; though some of the metalline hyposulphites have an intensely sweet taste.

Hyposulphurous acid cannot exist in a separate state. When we attempt to decompose the hyposulphites, we almost always resolve their acid into sulphurous acid and sulphur. It has been already shown in a preceding part of this work, that hyposulphurous acid is a compound of

1 atom sulphur = 2 or 100
1 atom oxygen = 1 50,

The hyposulphites precipitate silver from the nitrate in the state of sulphuret. Several of them have the property of dissolving and keeping in solution the chloride of silver.

SECT. XII.

OF HYPOSULPHURIC ACID.

Preparation.

This acid, recently discovered by Gay-Lussac and Welter, may be formed by passing a current of sulphurous acid through water, containing a mixture of peroxide of manganese. Add an excess of barytes to the solution and filter. A current of carbonic acid gas precipitates the excess of barytes present. Sulphuric acid is then to be added in such quantity as just to precipitate the whole of the barytes combined with the hyposulphuric acid. The liquid, being now filtered, is found to be a solution of hyposulphuric acid in water.

The acid thus obtained is colourless, has no smell; but a strong acid taste. When placed under the exhausted receiver of an air-pump, along with sulphuric acid, it may be concentrated till it reaches the specific gravity 1·347 without undergoing decomposition. But if the concentration be carried farther, or if heat be applied to the concentrated acid, it is decomposed into sulphurous and sulphuric acids, the former of which flies off while the latter remains behind.

When cold it is not altered by chlorine, concentrated nitric acid, or red sulphate of manganese. It saturates the different bases, and seems to form soluble salts with all of them. To these salts the name of hyposulphates has been given.

Book II. Division I.

Gay-Lussac and Welter have shown that this acid is a compound of 1 integrant particle of sulphuric acid and 1 integrant particle of sulphurous acid united together. Hence its constituents must be

2 atoms sulphur = 4
5 atoms oxygen = 5

9

And the equivalent number for it must be 9.*

Thus we have no fewer than 4 acid compounds of sulphur and oxygen. The constituents of these acids are as follows:

	Sulphur.	Oxygen.
Hyposulphurous acid	of 1 atom	+ 1 atom
Sulphurous acid	1	+ 2
Sulphuric acid	1	+ 3
Hyposulphuric acid	2	+ 5

SECT. XIII.

OF SELENIC ACID.

Preparation.

Selenic acid is easily formed by heating selenium in nitric acid or nitromuriatic acid. An effervescence ensues, and the selenium dissolves and is converted into selenic acid. On allowing the solution to cool, the selenic acid crystallizes in large six-sided prisms similar to the crystals of nitre. When these crystals are heated, the water which they contain is volatilized, and the acid remains behind in the state of a white mass. If the heat be augmented, the acid itself is converted into vapour without melting, and the vapour has very much the appearance of chlorine. The temperature at which the acid assumes the form of vapour is below the boiling point of sulphuric acid. The vapour condenses in the upper part of the apparatus in the form of very long tetrahedral needles, or, if the apparatus be rather hot, the acid is deposited in the form of a dense white mass, which has the appearance of some fusion, and is somewhat transparent. When exposed to the air it attracts moisture,

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* See Annals of Philosophy, xiv. 352.

loses its lustre, and becomes dull, but does not deliquesce into a liquid.

Properties.

Selenic acid has a sour taste which leaves a burning impression on the tongue. When in the gaseous state it has the sharp odour, which distinguishes acids in general, without any odour peculiarly its own. It is very soluble in cold water, and boiling water dissolves it in any proportion whatever. A saturated hot solution crystallizes on cooling in small grains or in striated prisms. It is likewise very soluble in alcohol.

When distilled with alcohol it forms an ether; while selenium is reduced, and the selenic acid which remains in the retort has a red colour in consequence of the excess of selenium which it contains. When a mixture of selenic acid, sulphuric acid, and alcohol is distilled, the substance which comes over into the receiver has an intolerably disagreeable odour. At the same time a considerable quantity of selenium is reduced.

When selenic acid is mixed with muriatic acid, and a plate of zinc put into the liquid, the selenic acid is decomposed and the selenium is precipitated in abundance. The selenic acid, in any solution, is easily decomposed by rendering the solution slightly acid, adding sulphate of ammonia, and boiling the mixture, the acid disengages the sulphurous acid, which deprives the selenic acid of its oxygen, and the selenium gradually precipitates in the state of a powder nearly black.

The salts which selenium forms when it combines with bases have received the name of *seleniates*. It has been already shown in a preceding part of this work,* that selenic acid is a compound of 1 atom of selenium and 2 atoms of oxygen. Hence its constitution is

Composition.

Selenium	5·125
Oxygen	2·000
	7·125

So that the weight of an integrant particle of this acid is 7·125.†

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* Vol. i. p. 306.

† Berzelius, Ann. de Chim. et de Phys. ix. 177 and 225.

SECT. XIV.

OF ARSENIC ACID.

Book II. Division I.

Preparation.

ARSENIC acid is usually prepared by the process pointed out by Scheele. Three parts of white oxide of arsenic are dissolved in 7 parts of muriatic acid, and the solution is mixed with 5 parts of nitric acid, and distilled to dryness. What remains is arsenic acid. But this method has been considerably improved by Bucholz. His method is as follows. Mix in a retort 1 part of muriatic acid of the specific gravity 1·2, 4 parts of the white oxide of arsenic, and 12 parts of nitric acid of the specific gravity 1·25. Boil the mixture till the oxide disappears and nitrous gas ceases to be disengaged. Then evaporate to dryness, and expose the mass for a few minutes to a low red heat. What remains after this is solid arsenic acid. But this acid may be prepared with still greater facility by dissolving metallic arsenic in nitric acid, evaporating the solution to dryness, re-dissolving the residuum in water, filtering the solution, and then evaporating it again to dryness.

Properties.

1. Arsenic acid, thus prepared, is a white solid mass, nearly tasteless. Its specific gravity is 3·391. It is very fixed. When heated strongly, it melts and remains transparent, and is converted into a glass, which acts powerfully on the vessel in which the experiment is performed. This glass attracts moisture from the air. When the heat is very strong, the acid gives out a little oxygen gas, and is at the same time partly converted into white oxide.

Action of water.

2. It dissolves very slowly in 6 parts of cold water; but 2 parts of boiling water dissolve it almost instantly, and it remains in a state of solution even though a considerable portion of that water be evaporated. With half its weight of water it has a syrupy consistency; and by farther evaporation it deposites crystals in grains.* Its taste, when liquid, is acid, caustic, and metallic.

II. Oxygen has no action whatever on this acid. The action of the other supporters of combustion on it has not been examined.

III. The simple acidifiable combustibles decompose it by the assistance of heat: and in these cases, as we learn from the

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* Bucholz, Jour. de Chim. iv. 5.

experiments of Scheele and of the Dijon Academicians, combustion sometimes takes place.

Several of the metals decompose it when assisted by heat. It does not act upon gold, platinum, silver, mercury. It oxidizes copper, iron, lead, tin, zinc, bismuth, antimony, cobalt, nickel, manganese, and arsenic, and in a strong heat, mercury and silver.

IV. It combines with alkalies, earths, and several of the metallic oxides, and forms compounds which have been called *arseniates*. Most of the arseniates are insoluble in water. But they all dissolve readily in nitric acid.

V. It appears established by the experiments quoted in a former part of this work,[*] that arsenic acid is a compound of

Arsenic	100
Oxygen	52·631

We concluded likewise that an atom of arsenic weighed 9·5, and of course that arsenic acid consists of

Arsenic	9·5	or 1 atom
Oxygen	5	5 atoms.

So that an integrant particle of it weighs 14·5.

SECT. XV.

OF ARSENIOUS ACID.

Arsenious acid is formed when arsenic is heated in the open air. It sublimes in a white smoke, which when collected constitutes arsenious acid.

It is usually in the form of a compact white cake; but it may be obtained also crystallized in octahedrons.

Properties.

It has an acrid taste which at last leaves an impression of sweetness and is one of the most virulent poisons in existence. It reddens vegetable blues and dissolves very scantily in cold water; but much more abundantly in boiling water.

II. None of the simple supporters are known to have any very powerful action on this acid. Oxygen is capable of combining with it; but the union cannot be accomplished by placing the two substances in contact.

III. The action of the simple combustibles on it has been

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[*] See vol. i. p. 306.

but imperfectly studied. There can be little doubt that hydrogen and carbon are capable of decomposing it when assisted by heat. The action of boron and silicon has not been tried. Probably sulphur and phosphorus would be able to convert it into sulphuret and phosphuret of arsenic.

There can be no doubt that potassium and sodium are capable of decomposing it.

When it is mixed with quicklime and the mixture is heated in a glass tube, a beautiful phenomenon may be observed. At a certain temperature the mixture becomes ignited, the combustion gradually pervading the whole mass. At the same time a quantity of metallic arsenic sublimes.* Thus it appears that a portion of the arsenious acid gives out its oxygen to another portion, which is thus converted into arsenic acid, and uniting with the lime constitutes an arseniate of lime. Perhaps the same phenomenon would be observed, if barytes or strontian were substituted for lime.

IV. Arsenious acid combines with the different bases and forms a genus of salts called *arsenites*, which have been very little examined by modern chemists. It is composed of

1 atom arsenic	9·5
3 atoms oxygen	3·
	12·5

So that an integrant particle of it weighs 12·5.

SECT. XVI.

OF ANTIMONIC ACID.

Preparation.

Antimonic acid, for the first description of which we are indebted to Berzelius, is obtained by mixing 1 part of antimony in powder with 6 parts of nitre, and exposing the mixture for an hour in a silver crucible to the greatest heat which the crucible can bear. The soluble portion of the nitre being now washed off, the white powder that remains is to be digested in water. A portion will dissolve. Into the solution drop acetic acid. A white powder falls which is antimonic acid in the state of a hydrate.

Properties.

In this state it is a white powder insoluble in water; but ca-

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* The experiment was made by Dr. Wollaston.

pable of reddening vegetable blues. When heated it gives out its water and assumes a yellow colour, and is no longer capable of reddening vegetable blues. When heated to redness it parts with a portion of its oxygen and is converted into *antimonious acid* or *white oxide of antimony.*

According to the analysis of Berzelius,[*] the hydrate of antimonic acid is a compound of

Antimonic acid	95·22	100
Water	4·78	5·02
	100·00	

Were we to suppose antimonic acid to be a compound of 1 atom antimony + 2 atoms oxygen, as it is probable it is, its weight would be 7·625, and the hydrate would be a compound of 3 atoms acid + 1 atom water.

II. The action of the supporters and of the combustibles on this acid still remains unknown. The compounds which it forms with bases, called *antimoniates*, have been examined by Berzelius. They will come under our examination in a subsequent part of this work.

SECT. XVII.

OF ANTIMONIOUS ACID.

Preparation.

ANTIMONIOUS acid is obtained by the combustion of antimony, or by dissolving antimony in nitric acid, and exposing the dry residuum after evaporation to a red heat.

The acid thus prepared is a fine white powder of a very white colour and having considerable lustre. It requires a pretty high temperature to fuse it; but it is volatilized at a lower temperature than the protoxide of antimony, and forms prismatic crystals, formerly known by the name of argentine flowers of antimony.

Composition.

When this acid is fused with one fourth of its weight of antimony, it is converted into protoxide of antimony. Hence it is obvious, that the oxygen in it must be to that in the protoxide of antimony as 4 to 3. If therefore the protoxide of antimony be a compound of 1 atom metal + 1 atom oxygen, we have no other alternative, but to consider antimonious acid as a compound of

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[*] Nicholson's Journal, xxxiv. 318.

Antimony	3 atoms
Oxygen	4 atoms

Such a constitution must be admitted to be very problematical; though there is nothing in the atomic theory, as far as we are aware at present, to lead us to reject it as impossible. The point might be decided by a knowledge of the constitution of the *antimonites.* For if antimonious acid be a compound of 3 atoms antimony + 4 atoms oxygen, its weight must be 20·875. Now this weight, great as it is, is confirmed by the constitution of the only antimonite hitherto analysed. According to the experiments of Berzelius,* antimonite of potash is composed of

Antimonious acid	100	19·64
Potash	30·55......	6

Thus the equivalent number for antimonious acid derived from this analysis is 19·64, which is within one twentieth of the number derived from the supposed constitution of the acid.

The facility with which the protoxide of antimony and the antimonic acid can be converted into antimonious acid leads one to suspect that they are of a complicated nature. But it would be singular indeed if the most permanent compound of antimony and oxygen consisted of 3 atoms of the former + 4 atoms of the latter, while the compounds consisting of 1 atom of each, or of 1 atom of the former combined with 2 atoms of the latter, were altered with the greatest facility. Yet it is possible that some peculiarity in the shape of the antimonic atom may account for this seeming anomaly.

SECT. XVIII.

OF CHROMIC ACID.

Preparation.

Chromic acid may be obtained from the chromate of iron by the following process for which we are indebted to Vauquelin. Mix two parts of the powdered ore with one part of nitre, and expose the mixture to a strong heat for several hours in a Hessian crucible. Digest the torrified mass in water till all the soluble portion is dissolved. The undissolved portion is a mixture of oxide of iron and undecomposed chromate. Dis-

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* Nicholson's Journal, xxxv. 44.

solve off the oxide of iron by means of muriatic acid, and mix the undecomposed chromate with an additional portion of nitre and torrefy it again. By this means it is completely decomposed. The water holding the potash and chromic acid in solution is to be saturated with nitric acid, and evaporated till the chromate of potash crystallizes. Dissolve this salt in water and precipitate the chromic acid by means of muriate of barytes. Wash the chromate of barytes well, and then dissolve it in nitric acid. Throw down the barytes by means of sulphuric acid added with caution to prevent an excess. Filter the liquid and evaporate it to dryness by a low heat. Add water and repeat the evaporation two or three times to get rid of the nitric acid. The dry mass is now chromic acid in a state of purity.

Properties.

Chromic acid, thus obtained, is a substance of a deep red colour. Its taste is acid, sharp, and strongly metallic. When exposed to the air it deliquesces. Water dissolves it, and it may be obtained from that liquid in elongated prisms of a ruby red colour.

When heated it gives out oxygen gas, and is converted into green oxide of chromium.

When mixed with filings of tin and muriatic acid, it becomes at first yellowish brown, and afterwards assumes a beautiful green colour.

When mixed with a little alcohol and nitric acid, it immediately assumes a bluish green colour, which preserves the same shade even after desiccation. Ether alone gives it the same colour.

With a solution of nitrate of mercury, it gives a precipitate of a dark cinnabar colour.

With a solution of nitrate of silver, it gives a precipitate which, the moment it is formed, appears of a beautiful carmine colour, but becomes purple by exposure to the light. This combination, exposed to the heat of the blowpipe, melts before the charcoal is inflamed. It assumes a blackish and metallic appearance. If it be then pulverised, the powder is still purple; but after the blue flame of the lamp is brought in contact with this matter, it assumes a green colour, and the silver appears in globules disseminated throughout its substance.

With nitrate of copper, it gives a chesnut-red precipitate.

With the solutions of sulphate of zinc, muriate of bismuth, muriate of antimony, nitrate of nickel, and muriate of platinum, it produces yellowish precipitates when these solutions do not contain excess of acid. With muriate of gold it produces a greenish precipitate.

When melted with borax or glass, it communicates to them a beautiful emerald-green colour.

Paper impregnated with chromic acid assumes in the light a greenish colour.

When mixed with muriatic acid, the mixture is capable of dissolving gold like aqua regia: when this mixture of the two acids is distilled, chlorine is disengaged, and the liquor assumes a very beautiful green colour.

Sulphuric acid, while cold, produces no effect upon it; but when warmed, it makes it assume a bluish green colour, probably by favouring the disengagement of oxygen.

The salts which chromic acid forms with bases have been examined by Vauquelin* and John.† They have received the name of *chromates*, and will be described in a subsequent part of this work.

SECT. XIX.

OF MOLYBDIC ACID.

Preparation.

Molybdic acid is usually prepared from molybdena, or native sulphuret of molybdenum, by the process pointed out by Scheele. Reduce the mineral to powder, and distil off it nitric acid, or rather a mixture of nitric and muriatic acids, till the whole is converted into a white mass. Edulcorate this mass with water to carry off the sulphuric acid formed, and the remains of the other acids. It is now molybdic acid tolerably pure.

Another method has been lately pointed out by Bucholz. Reduce the mineral to a fine powder, and expose it to heat in an open crucible, stirring it with an iron rod till the whole assumes an ash-grey colour. The heat is to be at first a strong red, but gradually lowered as the roasting advances, to prevent the powder from cohering, which would render the completion of the process very difficult. By this roasting the sulphur is dissipated, and a considerable portion of the metal acidified. Reduce the mass to powder, and digest it a sufficient time in water holding soda or ammonia in solution; the molybdic acid is taken up, and combines with the alkali, while the impurities remain behind. Let the solution remain corked up till it has become clear, decant it off from the sediment if any thing has

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* Ann. de Chim. lxx. 70.

† Annals of Philosophy, iv. 424.

subsided, and pour into it some muriatic acid. The molybdic acid precipitates in the state of a fine white powder, and may be easily separated and edulcorated.*

Properties.

Molybdic acid, thus prepared, is a white powder, the specific gravity of which is 3·460. When heated in a close vessel it melts and crystallizes; but in an open vessel it sublimes in a white smoke, which attaches itself to cold bodies, and assumes the form of brilliant yellow scales.

It is soluble in 960 parts of boiling water. The solution is pale yellow; it has no taste, but reddens litmus paper. The molybdic acid is precipitated from this solution by sulphuric, nitric, and muriatic acids.†

Molybdic acid is not affected by oxygen gas; but it is decomposed by sulphur and charcoal, and several of the metals. When heated with the protoxide of molybdenum, the mixture is converted into blue oxide.‡

It combines with alkalies, earths, and several metallic oxides, and forms salts known by the name of *molybdates*.

Sulphuric acid dissolves molybdic acid when assisted by heat. The solution is colourless while hot; but when cold it assumes a deep blue colour, which is heightened by saturating the solution with soda. When this sulphuric acid solution is heated strongly, the sulphuric acid is evaporated, and molybdic acid remains. Muriatic acid also dissolves it. The solution is of a pale yellowish green colour; but it becomes blue when saturated with potash. Nitric acid does not dissolve this acid.§

This acid, when combined with potash, forms a colourless salt.

Mixed with filings of tin and muriatic acid, it immediately becomes blue, and precipitates flakes of the same colour, which disappear after some time, if an excess of muriatic acid has been added, and the liquor assumes a brownish colour.

With the solution of nitrate of lead it forms a white precipitate, soluble in nitric acid.

When mixed with a little alcohol and nitric acid, it does not change its colour.

With a solution of nitrate of mercury, or of nitrate of silver, it gives a white flaky precipitate.

With the nitrate of copper it forms a greenish precipitate.

With solutions of sulphate of zinc, muriate of bismuth, mu-

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* Gehlen's Jour. iv. 604.

† Hatchett, Phil. Trans. lxxxvi. 323.

‡ Bucholz, Gehlen, iv. 626.

§ Hatchett, Phil. Trans. lxxxvi. 323.

riate of antimony, nitrate of nickel, muriates of gold and platinum, it produces white precipitates when these solutions do not contain an excess of acid.

When melted with borax, it gives it a bluish colour.

Paper dipped in this acid becomes in the sun of a beautiful blue colour.*

With respect to *molybdous acid* or blue oxide of molybdenum, it has been so imperfectly examined that I can add nothing to the few facts, which have been already stated, when treating of molybdenum.

SECT. XX.

OF TUNGSTIC ACID.

Preparation.

TUNGSTIC acid may be obtained by the following process for which we are indebted to Bucholz. Mix one part of wolfram in powder with two parts of carbonate of potash. Keep the mixture melted in a crucible for an hour, stirring it occasionally. Then pour it into an iron cone. Before the mass be quite cold reduce it to powder, and boil water on it repeatedly till the liquid comes off tasteless. Mix all the aqueous solutions together, and pour muriatic acid into them as long as any precipitate appears. Wash the precipitate, dissolve it in boiling carbonate of potash, precipitate again by muriatic acid, and after washing the precipitate digest it in nitric acid to remove any traces of potash that may still adhere to it. Then wash it and dry it. In this state it is tungstic acid in a state of purity.

Properties.

Tungstic acid, thus obtained, is a tasteless yellow powder insoluble in water, and producing no change on vegetable blues. It is capable, likewise, of assuming a blue colour, and though insoluble in water it remains long suspended in that liquid, forming a yellow-coloured milk.

The compounds which it forms with salifiable bases have received the name of *tungstates*. The alkaline tungstates are soluble and crystallizable. The earthy tungstates are insoluble, with the exception of the tungstate of magnesia. The same observation applies to the tungstates of the metallic oxides.

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* Vauquelin, Phil. Mag. i. 282.

SECT. XXI.

OF COLUMBIC ACID.

Subdivis. I. Chap. III.

It appears from the experiments of Hatchett and Berzelius that the white oxide of tantalum possesses acid properties. But I can add nothing to the few facts stated when treating of columbium.

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Such are the properties of the 22 acids, composed of a simple basis united to oxgen, as far as their properties have been investigated. The most important property which they possess is that of combining with the different salifiable bases and forming salts. The proportions in which they enter into these combinations depending upon the weight of their atom, it will be worth while to exhibit these weights as far as they have been determined. This is accordingly done in the following table.

Acids.	Constituents.			Atoms of		Weight of an atom base.	Weight of an atom acid.
	Base.		Oxygen.	Base.	Oxygen		
Nitric	Azote	100	285·8	1	5	1·75	6·75
Nitrous		100	228·57	1	4	..	5·75
Hyponitrous		100	171·43	1	3	..	4·75
Carbonic	Carbon	100	266·6	1	2	0·75	2·75
Boracic	Boron	100	228·57	1	2	0·875	2·875
Silica	Silicon	100	100	1	1	1	2
Phosphoric	Phosphorus	100	133·3	1	2	1·5	3·5
Phosphorous		100	66·6	1	1	..	2·5
Hypophosphorous		100	33·3	2	1	..	4
Sulphuric	Sulphur	100	150	1	3	2	5
Sulphurous		100	100	1	2	..	4
Hyposulphurous		100	50	1	1	..	3
Hyposulphuric		100	125	2	5	..	9
Selenic acid	Selenium	100	39·025	1	2	..	7·125
Arsenic	Arsenic	100	52·631	1	5	9·5	14·5
Arsenious		100	31·6	1	3	..	12·5
Antimonic	Antimony	100	35·556	1	2	5·625	7·625
Antimonious		100	23·7	3	4	..	20·875
Chromic	Chromium	100	87·72	1	3	3·5	6·5
Molybdic	Molybdenum	110	50	1	3	6	9
Molybdous			33·3	1	2	..	8
Tungstic	Tungsten	100	25	1	3	12	15
Columbic	Columbium	100	5·5	1	1	18	19

GENUS II. COMBUSTIBLE ACIDS.

Book II. Division I.

The acids belonging to this genus were formerly distinguished by the appellation of *vegetable* and *animal acids*, because almost the whole of them are procured from the vegetable and animal kingdom. They differ essentially from the preceding genus of acids in several particulars.

Properties.

1. If they be combined with potash and distilled, they are completely decomposed, charcoal is usually evolved, and a considerable quantity of heavy inflammable air extricated; whereas no combustible substance can be procured by exposing the other acids to heat.*

2. All of them contain at least two simple combustible substances as a base; whereas the others never contain more than one. These two substances are always *carbon* and *hydrogen*. Some of these acids contain likewise *azote*, over and above the two simple combustibles. Oxygen also usually enters into their composition in considerable quantity, but not perhaps always. To them, therefore, the theory of Lavoisier, respecting the necessity of oxygen as the acidifying principle does not strictly apply.

3. They do not seem capable of combining with different proportions of oxygen. Whenever the quantity of oxygen is changed, the proportion of the other constituents changes also. Of course the termination of their names ought not to indicate the proportion of oxygen which they contain; but should, if possible, be independent of that proportion altogether.†

Divisible into four orders.

4. The combustible acids may be very conveniently subdivided into four orders; which are distinguished from each other by the following properties:

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* Sulphurous and phosphorous acids excepted, which emit sulphur and phosphuretted hydrogen when exposed to heat.

† The French chemists who formed the new nomenclature were misled here. They made some of the names of the combustible acids end in *ic*, as if they were saturated with oxygen; and others in *ous*, as if they were capable of combining with an additional dose. The fact is, that none of them are, strictly speaking, saturated with oxygen; for all of them are capable of combining with *more*. But then they cannot combine with more without being totally decomposed, and converted into water, carbonic acid, &c. I have adopted the rule proposed by Mr. Chenevix, which is calculated to avoid all ambiguity; the names of all the combustible acids are made to end in *ic*, and this without reference to theory.

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The acids belonging to the first order are crystallizable, and they may be volatilized by heat without undergoing decomposition.

Those belonging to the second order are likewise crystallizable, but they cannot be volatilized without decomposition.

Those belonging to the third order are not crystallizable.

The fourth order contains three acids which do not seem capable of forming permanent salts with bases, and therefore must be deemed imperfect.

Order I. *Crystallizable and Volatile Acids.*

1. Acetic
2. Benzoic
3. Succinic
4. Moroxylic
5. Camphoric
6. Boletic
7. Suberic
8. Meconic
9. Lampic
10. Pyrotartaric
11. Pyromucic.

Order II. *Crystallizable, but not volatile.*

1. Oxalic
2. Mellitic
3. Tartaric
4. Citric
5. Kinic
6. Saclactic
7. Uric
8. Purpuric
9. Laccic
10. Malic
11. Igasuric.

Order III. *Uncrystallizable.*

1. Formic
2. Lactic
3. Krameric.

Order IV. *Imperfect acids.*

1. Gallic
2. Tannin
3. Ellagic.

I shall describe these acids in the following sections in the order in which they have been named.

SECT. I.

OF ACETIC ACID.

This acid is employed in three different states, which have been distinguished from each other by peculiar names. When first prepared, it is called *vinegar;* when purified by distillation, it assumes the name of distilled vinegar, usually called *acetous acid* by chemists; when concentrated as much as possible by peculiar processes, it is called *radical vinegar,* and by chemists *acetic acid.* It will be requisite to describe each of these states separately.

Vinegar.

1. Vinegar was known many ages before the discovery of any other acid, those only excepted which exist ready formed in vegetables. It is mentioned by Moses, and indeed seems to have been in common use among the Israelites and other eastern nations at a very early period. It is prepared from wine, from beer, ale, and other similar liquids. These are apt, as every one knows, to turn sour, unless they be kept very well corked. Now sour wine or beer is precisely the same with vinegar.

Boerhaave describes the following method of making vinegar, which is said to be still practised in different places.

Preparation.

Take two large oaken vats or hogsheads, and in each of these place a wooden grate or hurdle at the distance of a foot from the bottom. Set the vessel upright, and on the grate place a moderately close layer of green twigs of fresh cuttings of the vine. Then fill up the vessel with the footstalks of grapes, commonly called the *rape,* to the top of the vessel, which must be left quite open.

Having thus prepared the two vessels, pour into them the wine to be converted into vinegar, so as to fill one of them quite up, and the other but half full. Leave them thus for twenty-four hours, and then fill up the half-filled vessel with liquor from that which is quite full. Four-and-twenty hours afterwards repeat the same operation; and thus go on, keeping the vessels alternately full and half full during every twenty-four hours till the vinegar be made. On the second or third day there will arise, in the half-filled vessel, a fermentative motion, accompanied with a sensible hea which will gradually increase from day to day. On the contrary, the fermenting motion is almost imperceptible in the full vessel; and as the two vessels are alternately full and half full, the fermentaion is by that means, in some measure, interrupted, and is only renewed every other day in each vessel.

When this motion appears to have entirely ceased, even in the half-filled vessel, it is a sign that the fermentation is finished; and therefore the vinegar is then to be put into casks close stopped, and kept in a cool place. The process in summer usually lasts fifteen days; in winter it lasts longer.*

All that is necessary to convert wine or beer into vinegar is the contact of the external air, a temperature of 80°, and the presence of some substance to act as a ferment. But the theory of this operation belongs to the Second Part of this Work; our business at present is, not to investigate the method of making vinegar, but to examine the properties of acetic acid.

Properties.

Vinegar is a liquid of a reddish or yellowish colour, a pleasant sour taste, and an agreeable odour. Its specific gravity varies from 1·0135 to 1·0251, and it differs also in its other properties according to the liquid from which it has been procured. It is very subject to decomposition; but Scheele discovered, that if it be made to boil for a few moments, it may be kept afterwards for a long time without alteration. Besides acetic acid and water, vinegar contains several other ingredients, such as mucilage, tartar, a colouring matter, and often also two or more vegetable acids. When distilled at a temperature not exceeding that of boiling water, till about two-thirds, or five-sixths at most, of it have passed over, most of these impurities are left behind, and the product is pure acid, diluted with water. The residuum is still an acid liquid, and often lets fall crystals of tartar. But even when thus distilled it is not quite pure. Mr. Chenevix has shown that it still contains a peculiar mucilaginous or extractive matter, and traces of a spirituous liquor.

Mr. Phillips informs us that when the best English malt vinegar of the specific gravity 1·0204 is distilled, the first eighth is of the specific gravity 0·99712, and a fluid ounce of it (1·8047 cubic inches) dissolves from 4·5 to 5 grains of precipitated carbonate of lime. The next six-eights have the specific gravity 1·0023, and a fluid ounce dissolves 8·12 grains of precipitated carbonate of lime. A fluid ounce of acid of the specific gravity 1·007 dissolves from 15 to 16 grains of precipitated carbonate of lime, or 13·8 grains of marble.†

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* An account of the mode of making vinegar in France, almost precisely the same with that given in the text, was published in the Philosophical Transactions for 1670, vol. v. p. 2002. The methods at present practised in France are described in the 3d Volume of the Elemens de Chymie, published by the Dijon Academy, p. 6. Many still follow the process described in the text; others a different one.

† Phillips on the Pharmacopœia Londinensis, p. 7.

Acetous acid.

2. The acid thus obtained is a liquid as transparent and colourless as water, of a strong acid taste and an agreeable odour, somewhat different from that of vinegar. In this state it is usually called *acetous acid* or *distilled vinegar.*

It may be preserved without alteration in close vessels. When exposed to a moderate heat, it evaporates completely, and without undergoing any change in its properties. When exposed to the action of cold, part of it congeals. The frozen portion, which consists almost entirely of water, may be easily separated; and by this method the acid may be obtained in a high degree of concentration. The more concentrated the acid is, the greater is the cold necessary to produce congelation. Mr. Lowitz has ascertained that the acid itself how much soever it be concentrated, crystallizes or congeals at the temperature of — 22°.

Preparation of acetic acid.

3. When acetate of copper, reduced to powder, is put into a retort and distilled, there comes over a liquid at first nearly colourless and almost insipid, and afterwards a highly concentrated acid. The distillation is to be continued till the bottom of the retort is red-hot. What remains in it then is only a powder of the colour of copper. The acid product, which should be received in a vessel by itself, is tinged green by a little copper which passes along with it; but when distilled over again in a gentle heat, it is obtained perfectly colourless and transparent. The acid thus obtained is exceedingly pungent and concentrated. It was formerly distinguished by the names of *radical vinegar* and *vinegar of Venus.*

Supposed different from acetous.

This process was known to the alchymists, and had often been repeated by chemical philosophers; but the product was considered as merely highly concentrated acetous acid, till Berthollet published his experiments on it in 1785.* That skilful philosopher affirmed, that it differs from acetous acid in taste and smell, in its affinities for other bodies, and in the compounds which it forms with them. When it is obtained from acetate of copper by distillation, the powder which remains in the retort consists chiefly of copper in the metallic state. Hence he supposed, that the acetic acid gave out phlogiston to the copper, and received from it oxygen. When the existence of phlogiston was disproved, this theory was a little altered. It was concluded, that during the distillation, the acetic acid deprived the oxide of copper of its oxygen, and

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* Mem. Par. 1783.

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combined with it; and that radical vinegar therefore is acetous acid combined with a new dose of oxygen. For this reason it received the name of *acetic acid.*

This theory was generally admitted by chemists, till Mr. Adet published his experiments on acetic acid in 1797.[*] He observed, that when acetate of copper is distilled, the products are not only acetic acid and water, but likewise carbonic acid and carburetted hydrogen gas; and that the residuum consists of copper and charcoal. He found that acetous acid did not absorb oxygen when distilled off black oxide of manganese, and that acetic and acetous acids have exactly the same effect upon metals. From these and some other similar experiments, he concluded that acetic and acetous acids do not differ from each other except in concentration.

This conclusion was considered as hasty, as he did not attempt to account for the very striking difference in the taste and smell of these acids, as he had neither repeated nor refuted the experiments of Berthollet, on which the opinion of the difference between these two acids was founded. The conclusion of Adet was opposed, in 1798, by Chaptal, who published a set of experiments on the same subject.[†] This philosopher endeavoured to demonstrate, as Berthollet had done before him, that acetic and acetous acids, even when of the same strength, possess different properties, and have different effects on other bodies. From the effect of sulphuric acid upon each, and from the quantity of charcoal which remains in the retort when equal quantities of each saturated with potash are distilled, he concluded that acetous acid contains a smaller proportion of carbon than acetic acid. And this he considered as the cause of the difference in their properties.

In 1800, a new set of experiments on the same subject was published by Mr. Dabit of Nantes.[‡] This chemist endeavoured to prove that acetic acid contains a greater proportion of oxygen than acetous. When he distilled a mixture of acetate of potash and sulphuric acid, the product was acetic acid; but when he substituted muriatic acid for sulphuric, he obtained acetous acid: but when to this last mixture a little black oxide of manganese was added, he assures us that he obtained acetic acid. And in none of these cases was there any carbonic acid emitted till towards the end of the distillation.

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[*] Ann. de Chim. xxvii. 299.

[†] Ibid. xxviii. 113.

[‡] Ibid. xxxviii. 66.

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Proved to be the same.

The experiments of Darracq have at last finally settled this dispute by demonstrating that acetous and acetic acids differ merely in concentration. This able chemist repeated the experiments of Adet, which he found perfectly accurate, and performed several new ones; all of which left no doubt that acetous and acetic acids contain precisely the same proportion of oxygen. He next tried the opinion of Chaptal respecting the proportion of carbon in each. When equal quantities of acetic and acetous acids are combined with potash or soda, the dry salts distilled leave the same quantity of charcoal, and yield the same quantity of other products. When reduced to the same specific gravity, the two acids form precisely the same salts with all alkaline and earthy bases. Finally, acetous acid gradually becomes acetic acid when distilled repeatedly off dry muriate of lime; and in this case no gaseous body whatever is evolved. From these facts, it is impossible to entertain a doubt that the two substances are essentially the same, and that these apparent differences are owing to the great quantity of water with which acetous acid is diluted, and the mucilaginous matter which it still retains.*

The same results were obtained also by Proust, who had drawn the same conclusions before he became acquainted with Darracq's paper.† Henceforth the term *acetous acid* must either be wholly dropped by chemists, or employed in a sense different from what was formerly affixed to it.

Properties.

4. This acid is transparent and colourless like water. It has a peculiar aromatic smell when in the state of *acetous acid;* but concentrated acetic acid, when procured in the usual way, has an empyreumatic odour mixed with the natural smell of vinegar, owing to a small portion of oil formed during the process.‡

Another method of procuring this acid in a concentrated state has been proposed by different chemists, and brought to a state of perfection by Lowitz of Petersburg. Distil a mixture of three parts of acetate of potash and four parts of sulphuric acid, till the acetic acid has come over into the receiver. To separate the sulphuric acid with which it is in some measure contaminated, rectify the liquid by distilling it off a portion of acetate of barytes. The acid that comes over crystallizes in the receiver.

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* Darracq. Ann. de Chim. xli. 264.

† Jour. de Phys. lvi. 210.

‡ Ann. de. Chim. xxxvii. 111.

The specific gravity of *distilled vinegar* varies from 1·007 to 1·0095; but *radical vinegar* is much more concentrated, its specific gravity being as high as 1·080.* In that state it is extremely pungent and acrid; and when it is applied to the skin, it reddens and corrodes it in a very short time. It is exceedingly volatile; and when heated in the open air, takes fire so readily, that one would be tempted to suspect the presence of ether in it. It unites with water in any proportion; and when concentrated, the mixture evolves a good deal of heat.

Strength.

The specific gravity of acetic acid will not enable us to determine its strength. The specific gravity is a maximum when the liquid is a compound of 1 atom acid + 3 atoms water. When the proportion of water is either increased or diminished the specific gravity diminishes. Acid composed of 1 atom real acid + 1 atom water, and acid composed of 1 atom real acid + 9½ atoms water have nearly the same specific gravity. The following table drawn up chiefly from the experiments of Mollerat,† exhibits the specific gravity of acetic acid of various strengths.

Atoms.		Weight of		Sp. Gravity.
Acid.	Water.	Acid.	Water.	
1 +	1 —	100	14·78	1·0630
	2	100	25·21	1·0742
		100	37·99	1·0770
	3	100	48·43	1·0791
		100	52·94	1·0800
		100	59·38	1·0763
	4	100	71·90	1·0742
	5 —	100	83·90	1·0728
	6 +	100	116·25	1·0658
	7	100	127·73	1·0637
	9½	100	166·34	1·0630

5. Acid of the specific gravity 1·063 is the strongest which can be procured. It crystallizes at the temperature of 55°, and the crystals melt slowly when heated to 72½. Courtenvaux had long ago observed, that the last portions of acetic acid, which come over during the distillation, were susceptible of

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* Richter. Gehlen's Jour. iv. 11.

† Ann. de Chim. lxviii. 88.

crystallizing in a moderate cold. Lowitz proposed a very ingenious method to obtain this acid in the state of crystals. He makes distilled vinegar into a paste with well burnt charcoal, and exposes the mixture to a heat not above 212°. The watery part is driven off, and the acid remains. A stronger heat drives off the acid itself in a very concentrated state. By repeating this process it may be obtained in crystals. The process of that chemist, detailed above, is more recent, and in every respect preferable.

Action of heat.

II. Acetic acid requires a strong red heat for its decomposition. Mr. Chenevix passed it five times successively through a red hot porcelain tube without destroying it completely. But when the tube is filled with charcoal, the decomposition is complete.

Probably all the supporters of combustion would act upon this acid at a high temperature, as they are all capable of uniting with one or other of its constituents. But the experiment has not been tried with sufficient care. Indeed it would be difficult to distinguish between the action of heat and the influence of the supporter.

III. The action of the simple acidifiable combustibles on acetic acid has not been examined with any attention. But it is not probable that any fact of importance would result from such an examination.

It is capable of oxidizing iron, zinc, copper, nickel, tin. It does not act upon gold, silver, platinum, mercury, bismuth, cobalt, antimony, arsenic. Its action on tellurium, tungsten, molybdenum, uranium, titanium, and chromium, has not been tried.

Acetates.

IV. The compounds which it forms with the salifiable bases have received the name of *acetates*. They are all, without any exception, soluble in water.

Distillation of metalline acetates.

When the acetates are distilled in a retort, by means of a graduated heat always kept as low as possible, there comes over acetic acid diluted with water, and a peculiar inflammable liquid, to which Mr. Chevenix has given the name of *pyro-acetic spirit*. The metallic base, mixed with charcoal, remains in the retort; and there flies off a mixture of carbonic acid and heavy inflammable gas. The metallic base is usually reduced to the metallic state; and the more difficult this reduction is, the greater is the quantity of pyro-acetic spirit formed. The following table exhibits the result of the distillation of seven metalline acetates in a state of purity, as obtained by Mr. Chenevix:

		Acetate of silver.	Acetate of nickel.	Acetate of copper.	Acetate of lead.	Acetate of iron.	Acetate of zinc.	Acetate of manganese.
	Loss by the fire.	0·36	0·61	0·61	0·37	0·49		0·555
Residue in retort.	State of base.	Reduced.	Reduced.	Reduced.	Reduced.	Black oxide.	White oxide.	Black oxide.
	Charcoal.	0·050	0·14	0·055	0·04	0·02	0·05	0·035
Liquid products.	Sp. gravity.	1·0656	1·0398	1·0556	0·9407	1·011	0·8452	0·8266
	Propor. of acid.	107·309	41·731	81·868	3·045	27·236	2·258	1·285
	Spirituous liquor.	0	0·2	0·17	0·555	0·24	0·695	0·91
Gaseous products.	Carbonic acid.	8	35	10	20	18	16	20
	Carb. hydrogen.	12	60	34	8	34	28	32
	Total of gas.	20	95	44	28	52	44	52

The acetates of potash and of soda give a greater proportion of pyro-acetic spirit than any of the metalline acetates. When acetate of barytes is distilled, the whole liquid product consists of this spirit without any mixture of acid whatever.

Pyro-acetic spirit.

This pyro-acetic spirit, is quite the same in its properties, from whatever acetate it is procured. No other genus of salts tried, as the oxalates, tartrates, citrates, yield this spirit. Acetic acid is not converted into it by heat. Mr. Chenevix distilled the same proportion of acetic acid five or six times through a red hot porcelain tube; part of it was decomposed, the liquor became brown, and its specific gravity was diminished, but a considerable proportion remained unaltered. But if charcoal be put into the porcelain tube, the acid is destroyed by one distillation, and nothing obtained but water, carbonic acid, and heavy inflammable air.

Its properties.

Pyro-acetic spirit is a white and limpid liquid. Its taste is at first acrid and hot, but it becomes cooling, and in some sort urinous. Its smell is peculiar, and is compared by Mr. Chenevix to that of a mixture of oil of peppermint and bitter almonds. Its specific gravity, when as pure as possible, is 0·7864. It burns with a flame, white exteriorly, but of a fine blue within, and leaves no residue. It boils at the temperature of 165°. It mixes with water, alcohol, and volatile oils in any proportion. With hot olive oil also it mixes in any proportion; but with that oil cold it mixes only in certain proportions. It dissolves a little sulphur and phosphorus, and is an excellent solvent of camphor. When hot it dissolves wax and tallow. A portion of these substances precipitates as the solution cools, but water still occasions a considerable precipitate in it. It dissolves potash, and becomes darker coloured; but it may be obtained by distillation again unaltered. When mixed with sulphuric acid it blackens and is decomposed, and much charcoal is formed. When mixed with nitric acid it becomes yellow, and its properties are altered. Some oxalic acid is formed. Muriatic acid renders it brown. When distilled with this acid a combination takes place, and a substance is formed, possessing very different properties from muriatic ether. Thus it appears that pyro-acetic spirit is a liquid possessing properties peculiar to itself, and quite different from those, both of alcohol, ethers, and volatile oils. It deserves, of course, a peculiar place among compound combustibles.*

Constituents of acetic acid.

V. The first attempt to ascertain the constituents of acetic acid was made by Dr. Higgins. He distilled acetate of potash, and by that means decomposed the acetic acid. The products were collected and examined.† But at that time chemistry was not far enough advanced to entitle us to look for correct results from such an analysis. The subject has been more lately resumed, first by Gay-Lussac and Thenard, and afterwards by Berzelius. The former burnt a mixture of acetate of barytes and chlorate of potash. The acid was completely

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* Chenevix; Ann. de Chim. lxix. 5.

† Higgins on acetous acid, p. 26.

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converted into water and carbonic acid. The gaseous products being examined, and the quantity of acetic acid decomposed known, they were enabled to calculate its constituents.[*] Berzelius' analysis was conducted according to the same theoretical principles. But he was at more pains to obtain the salt upon which he operated quite free from water.[†] The following table exhibits the composition of acetic acid according to these chemists:

	Hydrogen.		Carbon.		Oxygen.		
Gay-Lussac ..	5·629	+	50·224	+	44·147	=	100 acid
Berzelius	6·35	+	46·83	+	46·82	=	100 acid

If we take the result of Berzelius as nearest the truth, it follows from it that acetic acid is formed of

3 atoms hydrogen weighing	0·375
4 ......carbon	3·000
3 ......oxygen	3·000

It is, therefore, a compound of 10 atoms, and the weight of an integrant particle of it is 6·375. This weight is confirmed by the constitution of the acetates. The following numbers indicate the composition of acetate of lime and acetate of lead, according to the analysis of Berzelius.[‡]

Acetate of lime.

Acetic acid	100	...... 6·615
Lime	54·8	...... 3·625

Acetate of lead.

Acetic acid	100	.... 6·432
Yellow oxide of lead	217·662	14

The equivalent number for acetic acid, according to the analysis of the first of these salts, is 6·615; according to the second it is 6·432. Now, as it is probable that neither of these salts was absolutely free from water, we may consider the coincidence between the weight of an atom of acetic acid given by them, and that given by the analysis of acetic acid, as sufficiently near.

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[*] Recherches Physico-chymiques, ii. 308.

[†] See a minute account of the precautions which he took, and the mode which he followed, in the Annals of Philosophy, iv. 323.

[‡] Annals of Philosophy, v. 174.

SECT. II.

OF BENZOIC ACID.

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Benzoin, or Benjamin, as it is sometimes called, is a kind of resin brought from the East Indies; obtained, according to Mr. Dryander, from the styrax benzoe, a tree which grows in the island of Sumatra. This substance consists partly of a peculiar acid, described as long ago as 1608, by Blaise de Vigenere, in his Treatise on fire and salt, under the name of *flowers of benzoin*, because it was obtained by sublimation; but it is now denominated *benzoic acid.*

Prepara- tion.

1. The usual method of obtaining this acid is to put a quantity of benzoin, coarsely powdered, into an earthen pot, to cover the mouth of the pot with a cone of thick paper, and then to apply a very moderate sand heat. The benzoic acid is sublimed, and attaches itself to the paper. This method was tedious and difficult; it being hardly possible to prevent the heat from scorching the benzoin, and volatilizing some empyreumatic oil, which soils and injures the acid sublimed. Neuman proposed moistening the benzoin with alcohol, and distilling it in a retort with a low heat. The acid comes over immediately after the alcohol, partly in crystals and partly of the consistence of butter.* Geoffroy ascertained, in 1738, that this acid may be obtained by digesting benzoin in hot water. A portion is taken up, which is deposited in crystals as the water cools. Scheele published a different method in 1775; which being easier and more productive than any of the preceding, is now preferred. This process is as follows: † Upon four parts of unslacked lime pour twelve parts of water, and after the ebullition is over add 96 parts more of water; then put twelve parts of finely pounded benzoin into a tinned pan; pour upon it first about six parts of the above milk of lime, mix them well together, and thus successively add the rest of the mixture of lime and water. If it be poured in all at once, the benzoin, instead of mixing with it, will coagulate, and run together into a mass. This mixture ought to be boiled over a gentle fire for half an hour with constant agitation; then take it from the fire, let it stand quiet for an hour, in order that it may settle; pour off the supernatent limpid liquor

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* Neuman's Chemistry, p. 294.

† Scheele, i. 124.

into a glass vessel. Upon the remainder in the pan pour 96 parts of pure water; boil them together for half an hour, then take it from the fire, and let it settle; add the supernatent liquor to the former; pour upon the residuum some more water, boil it as aforesaid, and repeat the same process once more. At last put all the residuums upon a filtre, and pour hot water several times upon them. During this process, the calcareous earth combines with the acid of benzoin, and separates it from the resinous particles of this substance. A small quantity of the resin is dissolved by the lime-water, whence it acquires a yellow colour. All these clear yellow leys and decoctions are to be mixed together, and boiled down to twenty-four parts, which are then to be strained into another glass vessel.

After they are grown cold, muriatic acid is to be added, with constant stirring, till there be no farther precipitation, or till the mass taste a little sourish. The benzoic acid, which was before held in solution by the lime, precipitates in the form of a fine powder.

Mr. Hatchett has observed, that when benzoin is digested in sulphuric acid, a great quantity of beautifully crystallized benzoic acid is sublimed. This process is the simplest of all, and yields the acid in a state of purity; it claims, therefore, the attention of manufacturers.*

Properties

2. Benzoic acid, thus obtained, is a fine light whitish powder, which is not brittle, but has rather a kind of ductility. Its taste is sweet, hot, and somewhat bitter. Its odour is slight, but peculiar and aromatic.† Its specific gravity is 0·657.‡ It hardly affects the infusion of violets, but it reddens that of turnsol, especially when hot.§

Heat volatilizes this acid, and makes it give out a strong odour, which excites coughing. When exposed to the heat of the blow-pipe in a silver spoon, it melts, becomes as fluid as water, and evaporates without taking fire. It only burns when in contact with flame, and then it leaves no residuum behind. When thrown upon burning coals, it rises in a white smoke. When allowed to cool after being melted, it hardens, and a radiated crust forms on its surface.‖ When distilled in

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* Hatchett's Additional Experiments on Tannin. Phil. Trans. 1805.

† This odour is owing to a small portion of aromatic oil which adheres to the acid. It has been obtained without any smell by Giese. See Phil. Mag. xiv. 331.

‡ Hassenfratz, Ann. de Chim. xxviii. 11.

§ Morveau, Encyc. Method. Chim. i. 44.

‖ Lichtenstein.

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close vessels, the greater part of it sublimes unaltered, but some of it is decomposed. This portion is converted almost entirely into oil and carburetted hydrogen gas.

3. This acid is not altered by exposure to the air. Two hundred parts of cold water dissolve 1 part of it;[*] but 1 part of it dissolves in 24½ parts of boiling water.[†]

II. Neither the simple supporters nor combustibles have any sensible action on it at the common temperature of the air, as far as is known. But very few experiments have been made on the subject.

Benzoates.

III. It combines with alkalies, earths, and metallic oxides, and forms salts known by the name of *benzoates.* The alkaline benzoates are soluble in water. So are the benzoates of barytes, strontian, and magnesia. Those of alumina, yttria, and lime, are but sparingly soluble. The only metallic salts which form insoluble precipitates when mixed with benzoate of ammonia are those of tellurium, mercury, and iron. Tellurium and mercury are precipitated white; iron orange. Berzelius[‡] has proposed benzoate of ammonia as an excellent agent for precipitating iron and separating it from other bodies with which it may be united. From the experiments of Hisinger the method appears to be a good one, provided the iron be in the state of peroxide and the liquid contain no excess of acid.[§]

IV. Concentrated sulphuric acid dissolves benzoic acid without heat, or any other change, except becoming somewhat brown: when water is poured into the solution, the benzoic acid separates, and coagulates on the surface without any alteration.[||] Nitric acid presents precisely the same phenomena, as does also the sulphurous acid. Neither the muriatic, nor the phosphoric acids dissolve it. Acetic acid, when hot, dissolves it precisely as water does; but it crystallizes again when the acid cools.[**]

Alcohol dissolves it copiously, and lets it fall on the addition of water.[††] Boiling alcohol takes up its own weight.[‡‡] One hundred parts of cold absolute alcohol dissolve scarcely 56 parts of benzoic acid.[§§]

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[*] Bucholz Gehlen's Journal für die Chemie, Physik und Mineralogie, ix. 340.

[†] Bucholz. ibid.

[‡] Afhandlingar, i. 171.

[§] Ibid. iii. 152.

[||] Lichtenstein.

[**] Ibid.

[††] Ibid.

[‡‡] Wenzel's Verwandtschaft, p. 302.

[§§] Bucholz, ibid.

This acid is sometimes used as a medicine, but much less frequently than formerly.

Constituents.

V. Benzoic acid has been analysed with much accuracy by Berzelius. According to his experiments,* it is a compound of

Hydrogen......	5·16 or	6 atoms	=	0·75
Carbon........	74·41	15	=	11·25
Oxygen........	20·43	3	=	3·00
				15·00

According to this analysis it contains 24 atoms, and an integrant particle of it weighs 15. The constitution of benzoate of lead agrees very well with this determination. According to the analysis of Berzelius,† it is composed of

Benzoic acid..........	100	14·893
Yellow oxide of lead ..	94	14

The equivalent for benzoic acid according to this salt is 14·893, which does not differ 1 per cent. from the number obtained by the analysis of the acid itself.

Sebacic acid.

Chemists had long suspected that an acid could be obtained from tallow, on account of the acrid nature of the fumes which it emits at a high temperature; but it was M. Grutzmacher who first treated of it particularly, in a dissertation *De Ossium Medulla*, published in 1748.‡ Mr. Rhades mentioned it in 1753; Segner published a dissertation on it in 1754; and Crell examined its properties very fully in two dissertations published in the Philosophical Transactions for 1780 and 1782. It was called at first *acid of fat*, and afterwards *sebacic acid*.

But at the period when these chemists made their experiments, the characteristic properties of the different acids were not sufficiently known to enable them to distinguish acids from each other with precision. Thenard examined the subject in 1801, tried all the processes of Crell and Guyton Morveau, and found that the acids procured by them were either acetic or the acid employed in the process. Thenard found, however, that a peculiar acid was formed during the distillation of tallow. To it he consigned the appellation of *sebacic acid*. The experiments of this chemist were repeated in 1804 by Mr. Rose, who obtained similar results, and confirmed all the observations of the French philosopher.§ The subject soon after

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* Annals of Philosophy, v. 181.

† Ibid.

‡ Leonhardi.

§ Gehlen's Jo [illegible] iii. 170.

was resumed by Berzelius, who in an elaborate dissertation, published in 1806, proved that the sebacic acid of Thenard is nothing else than benzoic acid contaminated with some unknown substance derived from the fat, which alters some of its properties, but from which it may be freed by proper precautions.* There does not therefore exist, as far as we know at present, any acid to which the name of sebacic acid belongs.

SECT. III.

OF SUCCINIC ACID.

History. AMBER is a well-known brown, transparent, inflammable body, pretty hard, and susceptible of polish, found at some depth in the earth, and on the sea-coast of several countries. It was in high estimation among the ancients both as an ornament and a medicine.—When this substance is distilled, a volatile salt is obtained, which is mentioned by Agricola under the name of *salt of amber ;* but its nature was long unknown. Boyle was the first who discovered that it was an acid.† From *succinum*, the Latin name of amber, this acid has received the appellation of *succinic acid.*

Mr. Pott seems to have been the first chemist who made a set of experiments to ascertain its properties, and who demonstrated that it differs from every other.‡

Preparation. 1. It is obtained by the following process: Fill a retort halfway with powdered amber, and cover the powder with a quantity of dry sand; lute on a receiver, and distil in a sand-bath without employing too much heat. There passes over first an insipid phlegm; then a weak acid, which according to Scheele, is the acetic;§ then the succinic acid attaches itself to the neck of the retort; and if the distillation be continued, there comes over at last a thick brown oil, which has an acid taste.

The succinic acid is at first mixed with a quantity of oil. It may be made tolerably pure by dissolving it in hot water, and putting upon the filter a little cotton, previously moistened with oil of amber: this substance retains most of the oil, and allows the solution to pass clear. The acid is then to be crystallized

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[*] Afhandlingar, i. 170.

[†] Boyle abridged by Shaw, iii. 369.

[‡] Mem. Berlin. 1753. See an abstract of his paper in Lewis's edition of Neuman's Chemistry, p. 237.

[§] Bergman's Notes on Scheffer.

by a gentle evaporation; and this process is to be repeated till the acid be sufficiently pure. Guyton Morveau has shown that it may be made quite pure by distilling off it a sufficient quantity of nitric acid, taking care not to employ a heat strong enough to sublime the succinic acid.*

Properties.

2. The crystals of succinic acid are transparent, white, shining, and of a foliated, triangular, prismatic form: they have an acid taste, but are not corrosive: they redden tincture of turnsol, but have little effect on that of violets.

They sublime when exposed to a considerable heat, but not at the heat of a water-bath. In a sand-bath they melt, and then sublime and condense in the upper part of the vessel; but the coal which remains shows that they are partly decomposed.†

3. One part of this acid dissolves in 96 parts of water at the temperature of 50°, according to Spielman;‡ in 24 parts at the temperature of 52°; and in 2 parts of water at the temperature of 212°, according to Stockar de Neuforn;§ but the greatest part crystallizes as the water cools. According to Roux, however, it still retains more of the acid than cold water is capable of dissolving.||

Two hundred and forty grains of boiling alcohol dissolve 177 of this acid; but crystals again shoot as the solution cools.**

4. Sulphuric acid dissolves it with the assistance of heat; but does not appear to decompose it. The same remark applies to nitric acid. Muriatic acid has but little action on it while cold; but when heat is applied, the whole coagulates into the consistence of a jelly.††

5. The compounds which this acid forms with alkalies, acids, and metallic oxides, have received the name of *succinates*. The alkaline succinates are soluble in water. This is the case also with the earthy succinates, except succinate of barytes. Hence barytes is the only earth precipitated from a neutral solution by succinate of ammonia. This salt likewise precipitates mercury and lead. It throws down iron from all solutions provided the iron be in the state of peroxide, and there be no excess of acid present.

Constituents.

6. This acid has been analysed with much precision by Berzelius.‡‡ According to his experiments it is composed of

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* Ann. de Chim. xxix. 165.

† Pott.

‡ Inst. Chem. § xii.

§ De Succino.

|| Morveau, Encyc. Method. Chim. i. 72.

** Wenzel's Verwandtschaft, p. 305.

†† Pott.

‡‡ Annals of Philosophy, v. 99.

Hydrogen ..	4·512	or 2 atoms	= 0·25
Carbon	47·600	4	= 3·00
Oxygen	47·888	3	= 3·00
			6·25

According to this analysis it is a compound of 9 atoms, and an integrant particle of it weighs 6·25.

The constitution of succinate of lead as determined by Berzelius almost exactly agrees with this weight. According to him it is composed of

Succinic acid	100	6·26
Yellow oxide of lead	223·62	14

The equivalent for succinic acid according to these numbers is 6·26, which scarcely differs from 6·25 determined by the analysis of the acid.

The only difference between succinic and acetic acids, as far as their composition is concerned, consists in this, that acetic contains 1 atom of hydrogen more than succinic acid does; the atoms of the other constituents are the same in both.

SECT. IV.

OF MOROXYLIC ACID.

History.

About the year 1802, Dr. Thompson observed a saline exudation on the bark of the *morus alba*, or white mulberry tree, growing in the botanical garden of Palermo in Sicily. It coated the bark of the tree in small grains of a yellowish and blackish brown colour. A quantity of this matter was collected and sent to Mr. Klaproth, who published an analysis of it in 1803.*

It has a taste resembling that of succinic acid; and when placed upon burning coals, it emits a vapour which irritates the organs of smell. In water it dissolves sparingly, forming a reddish brown liquid, which yields by evaporation small needleform crystals, of the colour of pale wood, not deliquescing in the air. By dissolving these crystals in water, and treating them with various reagents, Klaproth ascertained them

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* Scherer's Journal der Chemie, No. 55, p. 1. But I use the translation of the paper published in Nicholson's Journal, vii. 129.

to be formed of lime united to a peculiar acid, which he called *moroxylic*, because the salt containing it was a production of the *wood of the mulberry tree*.

The salt dissolves but sparingly in water; hot water taking up only 0·035, and cold 0·015 of it. From the solution the alkaline carbonates precipitate lime; but barytes causes no precipitate; a proof of the absence of sulphuric acid. It precipitates powerfully the solutions of silver, mercury, copper, iron, cobalt, and uranium, in nitric acid; and of lead and iron in acetic acid. Barytes water, acetate of barytes, muriate of tin, muriate of gold, and nitrate of nickel, produce scarcely any effect.

To obtain the acid, the solution of the salt was treated with acetate of lead. Forty-five grains of the precipitate thus obtained were mixed with 20 grains of sulphuric acid diluted with 60 grains of water. The sulphate of lead formed remained in the state of a white powder, while the moroxylic acid was dissolved and obtained by evaporation in the state of fine needles of the colour of pale wood.

Properties.

The acid thus obtained has the taste of succinic acid: it is not altered by exposure to the air: it dissolves readily in water and in alcohol: it does not precipitate the metallic solutions like its salt.

When heated in a retort, a little acid liquor first comes over, which has the taste of the concrete acid: next, the acid rises unaltered, and adheres to the top and neck of the retort in colourless and transparent prismatic crystals. A coaly residuum remains in the vessel. Hence it appears, that a gentle sublimation is the best mode of obtaining this acid in a state of purity.

When the moroxylate of lime is distilled, a quantity of inflammable air mixed with carbonic acid is obtained, and an acid liquor comes over, on which swims a brown oil. There remains in the retort a spongy mass of a pale brown colour, consisting of carbonate of lime mixed with some charry matter. From these phenomena it appears, that this acid, like the rest, is composed of oxygen, hydrogen, and carbon, though the proportion of the constituents is unknown. The compounds which it forms with alkalies have received the name of *moroxylates*.

Such are the properties of this substance ascertained by Klaproth. The small quantity of the salt which he possessed prevented a more complete examination.

SECT. V.

OF CAMPHORIC ACID.

Book II. Division I. History.

Camphor is a well-known white crystalline substance, of a strong taste and smell, obtained from a species of laurel in the East Indies. It is so volatile that it is not readily melted in open vessels, and so inflammable that it burns even on the surface of water.

When camphor is set on fire in contact with oxygen gas, it burns with a very brilliant flame; much caloric is disengaged, water is formed, the inner surface of the vessel is covered with a black matter, which is undoubtedly charcoal, and a quantity of carbonic acid gas is also produced.* Hence it follows, that it is composed of hydrogen and carbon, at least principally.

Mr. Kosegarten, by distilling nitric acid off camphor eight times successively, obtained an acid in crystals,† to which the name of *camphoric acid* has been given.

Preparation.

1. His experiments have been repeated by Mr. Bouillon Lagrange. The process for obtaining camphoric acid, as described by this chemist, is as follows: Put into a retort 1 part of camphor and 8 parts of nitric acid, of the specific gravity 1·33. Distil with a sand heat. A great deal of nitrous gas and carbonic acid gas is emitted, and a little camphor sublimes. This process must be repeated three times on the same camphor; so that 24 parts in all of nitric acid are necessary. After the third distillation, when the retort is allowed to cool, a number of crystals make their appearance in it. These are *camphoric acid.* They amount to somewhat less than the half of the camphor employed.

The experiments of Kosegarten and Bouillon Lagrange were confirmed in 1810, by Bucholz, who employed the following process for converting camphor into camphoric acid. Two ounces of camphor are put into a retort with 1½ lb. of nitric acid of the specific gravity 1·250, and half a pound of fuming nitric acid of the specific gravity 1·550. A moderate heat is applied, and about one half of the acid is distilled off. This process is repeated three times, pouring back the acid which has distilled over each time. After the third distillation the camphoric acid is observed swimming on the acid in the

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* Bouillon La Grange, Ann. de Chim. xxiii. 153.

† Kosegarten, De Camphora, &c. 1785.

retort like a butyraceous mass, after the whole has become cold. It is separated from the nitric acid by means of a glass funnel. When washed and dried it is camphoric acid in a state of purity.

Properties.

2. Camphoric acid thus obtained is in snow-white crystals, the primitive form of which is a parallelopipedon.[*] These crystals effloresce in the air.[†] The usual crystalline form of this acid is feather shaped, like that of salammoniac.[‡]

Camphoric acid has a slightly acid bitter taste, and a smell like that of saffron.

It reddens vegetable colours.

3. It is soluble in 100 parts of cold water, according to Bucholz;[§] in 96 parts of water at the temperature of 60°, according to Bouillon Lagrange. Boiling water dissolves $\frac{1}{11}$th of its weight.[||]

100 Grains of absolute alcohol dissolve 106 grains of camphoric acid. The solution has the consistency of a thin syrup. Boiling alcohol dissolves any quantity of it whatever.[**]

Action of heat.

4. When this acid is placed on ignited coals, it emits a dense aromatic fume, and is entirely dissipated. By a gentler heat it melts, and is sublimed. If it be put into a heated porcelain tube, and oxygen gas be passed through it, the acid does not undergo any change, but is sublimed. By mere distillation it first melts, and then sublimes unaltered.[††]

5. Camphoric acid does not produce any change on sulphur; the mineral acids totally dissolve it; and so likewise do the volatile and the fat oils.

Camphoric acid does not precipitate lime from lime water. It produces no change on the solution of indigo in sulphuric acid.

6. It forms combinations with the alkalies, earths, and metallic oxides, which are called *camphorates*.

SECT. VI.

OF BOLETIC ACID.

Discovery.

This acid was discovered in 1811, by M. H. Braconnot,

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[*] Kosegarten, De Camphora, &c. 1785.

[†] Lagrange.

[‡] Bucholz, Gehlen's Journal für die Chemie, Physick, und Mineralogie, ix. 339.

[§] Ibid.

[||] Ibid.

[**] Ibid.

[††] Ibid.

while examining the expressed juice of the *boletus pseudo-igniarius.** He obtained it by the following process. The juice of the boletus was evaporated to a thick syrup by a very low heat. The residual matter was digested in alcohol. The portion left undissolved by the alcohol was dissolved in water, and nitrate of lead dropped into the solution. A white precipitate fell, which being edulcorated was mixed with water, and decomposed by a current of sulphuretted hydrogen gas. The liquid being filtered and evaporated exhibited two distinct acids. The one, which existed only in small quantity, was phosphoric acid, and deliquesced when exposed to the air. The other constituted permanent crystals. It was *boletic acid.* To obtain it in a state of purity it was dissolved in alcohol, and crystallized by evaporating the solution. In this state it possesses the following properties.

Properties. 1. Its colour is white, it is not altered by exposure to the air, and consists of irregular four sided prisms.

2. Its taste is similar to that of tartar. It requires 180 times its weight of water to dissolve it at the temperature of 68°. It is soluble in 45 times its weight of alcohol.

3. The aqueous solution reddens vegetable blues. Nitrate of lead occasions a precipitate in it which is redissolved by agitation. It precipitates the red oxide of iron from its solutions completely in the form of rust-coloured flocks; but it does not throw down the black oxide of this metal. It precipitates nitrate of silver in the state of a white powder which is soluble in nitric acid. Nitrate of mercury is precipitated in the same state; but the precipitate dissolves with difficulty in nitric acid. Neither lime water nor barytes water produces any effect upon the aqueous solution of this acid.

4. When heated it rises in white vapours, which irritate the throat, and condense on surrounding bodies in the form of a farinaceous powder. When distilled the greatest part sublimes unaltered, excepting that it afterwards crystallizes more regularly. At the same time a little liquid appears having a strong smell of acetic acid.

Salts. 5. Boletate of ammonia is a salt which crystallizes in flat four-sided prisms, and is soluble in 26 times its weight of water at 68°. Its taste is cooling, saline, and somewhat sharp. When heated it melts, swells, and sublimes. It precipitates red oxide of iron; but does not alter sulphates of lime, alumina, or man-

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* Ann. de Chim. lxxx. 272.

ganese. It slowly precipitates nitrate of copper in blue silky needles.

6. Boletate of potash is very soluble in water, and crystallizes with difficulty. Acids precipitate the boletic acid from it.

7. When boletic acid is heated with carbonate of lime it dissolves it with effervescence. The boletate of lime crystallizes in flat four-sided prisms. This salt has little taste, and requires at least 110 times its weight of water at the temperature of 72½° to dissolve it. It is decomposed by oxalic and sulphuric acids.

8. Boletate of barytes is an acidulous salt in white plates little soluble in water or nitric acid. When thrown on a red-hot iron it burns rapidly with a red flame and striking scintillations, leaving for residue carbonate of barytes.

9. When this acid is heated with iron filings and water, hydrogen gas is emitted, and a yellow liquor is obtained with an inky taste.

Such are the properties of boletic acid as they have been ascertained by Braconnot. Hitherto no other chemist has repeated his experiments.

SECT. VII.

OF SUBERIC ACID.

History.

Cork, a substance too well known to require any description, is the bark of a tree which bears the same name. By means of nitric acid Brugnatelli converted it into an acid,[*] which has been called the *suberic acid,* from *suber*, the Latin name of the cork tree. Several chemists affirmed that this acid was the oxalic, because it possesses several properties in common with it. These assertions induced Bouillon Lagrange to undertake a set of experiments on suberic acid. These experiments, which have been published in the 23d volume of the *Annales de Chimie*, completely establish the peculiar nature of suberic acid, by showing that it possesses properties different from those of any other acid. Chevreul has published a new set of experiments on it still more lately, which both serve still further to establish its peculiar nature, and make us better acquainted with its properties.[†]

Chevreul obtained this acid by digesting 1 part of cork in 6

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[*] Crell's Annals, 1787.

[†] Nicholson's Journal, xxiii. 149.

parts of acid. After the acid had ceased to act, the whole was evaporated to the consistence of an extract, hot water was poured over it, and the mixture was digested for some time in a sand heat. When set aside, a matter like wax formed on the surface, and white tasteless flocks precipitated to the bottom. These substances were separated, and the liquid concentrated by evaporation. Suberic acid precipitated in powder, and towards the end of the process crystals of oxalic acid formed. I observed the formation of oxalic acid some years ago, while treating cork with nitric acid.

Properties. Suberic acid thus formed may be purified by washing it in cold water. It is then white like starch, and has an acid taste without any bitterness. Light does not alter its whiteness. Water, at the temperature of 140°, dissolves $\frac{1}{38}$th of its weight of this acid, and $\frac{1}{80}$th at the temperature of 55·5°. When heated it melts, and on cooling crystallizes in needles. When heated in a retort it is volatilized, and condenses on the upper part in long needles. It does not precipitate lime, barytes, or strontian water, nor the salts containing these alkaline earths. The alkalies dissolve it very well, and form with it neutral salts. It precipitates nitrate of silver, muriate of tin, sulphate of iron, nitrate and acetate of lead, and nitrate of mercury, but it does not precipitate sulphate of copper or sulphate of zinc.

Nitric acid has no action on it. It dissolves in alcohol. It does not alter the colour of sulphate of indigo, provided it is free from yellow bitter matter.* These properties show a strong resemblance between this acid and the benzoic, though it differs in several respects.

SECT. VIII.

OF MECONIC ACID.

History. This acid exists in opium, probably in combination with morphia. It was discovered by M. Sertürner, and called by him *meconic acid*, from the Greek word *μηκων*, *a poppy*. Various modes of extracting this acid from the infusion of opium have been proposed; but none of them seems to be very good. The following process, which was contrived by Robiquet, yields meconic acid, but we do not succeed by it in obtaining the whole of that acid which exists in the liquid.

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* Nicholson's Jour. xxiii. 149.

Preparation.

Boil the infusion of opium with rather a greater quantity of magnesia than is sufficient to precipitate the whole of the morphia. Digest the precipitate in alcohol till the whole of the morphia is dissolved. There remains behind a quantity of magnesia united with meconic acid. Sulphuric acid dissolves this matter, and forms with it a brown coloured solution. Muriate of barytes being dropt into the solution, a precipitate falls, consisting of sulphate of barytes, and meconate of barytes slightly tinged red. Weak sulphuric acid being long digested upon this precipitate, decomposes the meconate; the meconic acid dissolves in the water, while the sulphate of barytes remains behind. The water being evaporated, allows the meconic acid to deposite in the form of brown crystals. In this state it is contaminated with a colouring matter which renders it much less soluble in water than when pure, and causes the meconate of magnesia and of barytes to precipitate; for when these salts are pure, they are soluble in water. These brown crystals are to be dried at a low temperature, and then to be exposed to a higher temperature, but one not sufficiently high to decompose the colouring matter. The meconic acid sublimes, and is deposited on the upper part of the retort.

Meconic acid thus obtained is white, and is usually crystallized in long needles, or square plates, though sometimes it affects other forms. It melts when heated to the temperature of about 250°, and as soon as melted, it begins to sublime without any decomposition.

Properties.

It is exceedingly soluble, both in water and alcohol. Its taste is acid, and it reddens vegetable blues. It combines with the different bases, and forms salts, distinguished by the name of *meconates*. The meconates of potash, soda, and ammonia, are soluble in water. This is the case also with the meconates of barytes, lime, and magnesia.

When meconic acid is dropt into solutions of the peroxide of iron, it strikes a strong red colour, similar to the change produced upon the same saline solutions by the sulpho-chyazic acid. But it does not occasion any precipitation in these liquids. When dropt into a solution of sulphate of copper, the colour of the liquid changes to a fine emerald green. No precipitate falls at first: but a pale yellow powder at last falls. This acid likewise produces slowly a precipitate in the solution of corrosive sublimate.*

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* Robiquet, Ann. de Chim. et de Phys. v. 282.

SECT. IX.

OF LAMPIC ACID.

Book II. Division I. Discovery. This is an acid formed when ether is consumed by means of a coil of platinum wire heated and plunged into the vapour of ether. The wire becomes red hot, and continues at that temperature till the whole of the vapour of ether be consumed. This curious experiment was first made by Sir H. Davy, and he recognised, that during the decomposition of the ether, a peculiar acid was formed. Some experiments on this acid were made afterwards by Mr. Faraday. But it is to Mr. Daniell that we are indebted for a satisfactory description of its properties. He employed the common spirit of wine lamp, with a coil of platinum wire fitted to it in the usual manner. It was filled with ether, and after being properly trimmed and kindled, was blown out. The platinum wire, as is well known, becomes immediately red hot, and continues so till the whole of the ether is consumed. Mr. Daniell placed it in the head of a common alembic, and adjusted a receiver to the beak of the vessel. When the lamp was properly placed, he succeeded in keeping the wire red hot for six weeks together, and he collected about a pint and a half of the condensed vapour. To this liquid he has thought proper to give the name of *lampic acid.*

Properties. Lampic acid thus collected, is a colourless liquor, having an intensely sour taste, and a pungent odour. Its vapour when heated is extremely irritating and disagreeable, and when received into the lungs, produces an oppression at the chest, very much resembling the effect of chlorine.

Its specific gravity varies from below 1·000 to 1·008. It may be purified by careful evaporation, and the vapour which rises according to Mr. Daniell, is that of alcohol, not of ether. When thus rectified, its specific gravity is 1·015. It reddens vegetable blues.

Mr. Daniell combined this acid with the different bases. All the earthy and alkaline lampates are soluble in water, and possess, as far as Mr. Daniell has described them, very nearly the properties of the corresponding acetates.

This acid throws down gold, platinum, silver, mercury, from their acid solutions in the metallic state. Lampate of copper crystallizes in blue rhomboids. Lampate of lead is a white crystallizable salt of a sweet taste.

When sulphuric acid is mixed with lampic acid, the colour becomes black, and charcoal is evolved. When lampic acid precipitates the gold, platinum, silver, and mercury in the metallic state, carbonic acid gas is evolved.

Mr. Daniell determined the compositions of lampate of soda, and lampate of barytes, as follows:

Lampate of soda.			Lampate of barytes.		
Acid	62·1	6·554	Acid	39·5	6·365
Soda	37·9	4	Barytes	60·5	9·75

Lampate of barytes by another experiment was found a compound of

Acid	40·2	6·554
Barytes	59·8	9·75

Seems the same as acetic.

Thus the equivalent number for lampic acid is 6·554 from the lampate of soda, and 6·365, or 6·554, from the two different analyses of lampate of barytes. The reader cannot fail to observe how nearly these numbers approach to 6·375, the weight of an integrant particle of acetic acid. This near coincidence, together with the properties of the lampates, as described by Mr. Daniell, leads me to suspect that lampic acid is nothing else than the acetic acid disguised a little by the presence of some ether and alcohol, or some oily matter, formed during the slow combustion of the ether. The presence of ether, or even alcohol, would account for the precipitation of the noble metals in the metallic state; while the salts formed seem to be acetates: the only fact, which seems inconsistent with this supposition, is the blue colour which Mr. Daniell informs us distinguishes the lampate of copper. For it is well known that the acetate of copper has a verdigris green colour.

Mr. Daniell attempted to analyse the lampic acid by burning lampate of barytes, with chlorate of potash. He consumed 7·3 grains of this salt, containing 2·9 grains of lampic acid. The only product obtained was 9·1 cubic inches of carbonic acid gas. Four cubic inches of the oxygen yielded by the chlorate of potash had disappeared, besides the quantity which existed in the carbonic acid. Now 4 cubic inches of oxygen gas in order to form water, must have united with 8 cubic inches of hydrogen gas. So that the constituents evolved by this experiment from 2·9 grains of lampic acid, were

9·1 cubic inches carbon .... = 1·157 grains.
8 cubic inches hydrogen .. = 0·169 grains.

Total .... 1·326

This subtracted from 2·9 grains, the original weight of the acid leaves 1·574 grains. This Mr. Daniell supposes to have been evolved in the state of water. Now 1·574 grains of water is very nearly equal to 8 cubic inches of steam; and 8 cubic inches of steam are resolvable into 4 cubic inches of oxygen gas, and 8 cubic inches of hydrogen gas. If we add these to the carbon and hydrogen formerly evolved, we see that the 2·9 grains of lampic acid were resolved into

9 volumes carbon .... = 4·5 atoms carbon .. = 3·375
16 volumes hydrogen .. = 8 atoms hydrogen = 1·
4 volumes oxygen .... = 4 atoms oxygen . = 4·

8·375

But as the number 8·375, the weight of the atom of lampic acid, does not correspond with the equivalent number for the acid deduced from the analysis of lampate of soda and lampate of barytes, it is obvious that Mr. Daniell must have fallen into some inaccuracy. Indeed I doubt whether the mode adopted by Mr. Daniell be susceptible of much precision. It has been abandoned by Gay-Lussac himself, who was its original inventor.*

SECT. X.

OF PYROTARTARIC ACID.

History.

The salt called *tartar* separates from wine while in the cask, and is afterwards purified by solution in water and subsequent evaporation. This salt occupied the attention of chemists very much from the time of Paracelsus, who first brought it into vogue. It was considered as an acid salt of a peculiar nature. The potash which constitutes its base was easily discovered by subjecting the salt to combustion. But the efforts of chemists to obtain the acid which it manifestly contained were long unsuccessful. When tartar was distilled in a retort, an acidulous liquid was obtained; but it was manifestly different from the acid in tartar, as tartar was not formed when it was united to potash. At last in 1770, Scheele discovered a process by which pure tartaric acid could be obtained from tartar. Its properties being manifestly different from that of the acid obtained by distilling tartar, as far as could be collected from the

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* Journal of Science and the Arts, vi. 318.

rude experiments of the Dijon Academicians,* the French chemists when they contrived the new chemical nomenclature distinguished them by the names of *tartarous* and *pyrotartarous acids;* which were afterwards changed into those of *tartaric* and *pyrotartaric* acids.† In the year 1799 a set of experiments was published by Fourcroy and Vauquelin on *pyromucous, pyrotartarous, pyrolignous* acids, the object of which was to prove, that these acids are merely the acetic disguised by some empyreumatic oil, with which it has combined.‡ This conclusion appears to have been acquiesced in by chemists without examination: though the proofs as far as regards the pyrotartaric acid are far from satisfactory; till Gehlen called it in question in 1806, affirming that pyrotartaric acid differs essentially from acetic, and stating some characters by which they could be easily distinguished.§ This induced Fourcroy and Vauquelin to repeat their experiments in 1807.‖ The result was a full confirmation of the opinion of Gehlen.

Preparation.

Pyrotartaric acid may be obtained by the following process. Distil a quantity of tartar in a retort. Saturate the acid liquid in the receiver with potash, separate the salt by crystallization, and purify it by repeated solutions and crystallizations. Mix this salt with diluted sulphuric acid, and distil in a retort. An acid liquid passes over, and towards the end of the process a white sublimate rises and attaches itself in scales to the top of the retort. This sublimate is *pyrotartaric acid.* When the acid liquor in the receiver is subjected to spontaneous evaporation it deposites crystals of pyrotartaric acid.

Properties.

The taste of pyrotartaric acid is extremely acid. When heated it melts, and sublimes in a white smoke, without leaving any residue. It dissolves readily in water, and crystallizes again when subjected to spontaneous evaporation. It does not precipitate acetate of lead nor nitrate of silver; but it precipitates nitrate of mercury. Some time after it has been mixed with acetate of lead, needleform crystals make their appearance.

When combined in excess with potash, no salt similar to tartar is formed. In this state it instantly forms a precipitate

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* Elemens de Chymie de l'Acadamie de Dijon, iii. 55.

† It was Morveau in the first volume of the chemical part of the Encyclopædie Methodique, published in 1786, that first drew the attention of chemists to pyrotartaric acid, and endeavoured to characterize it as a peculiar acid. His characters were inaccurate, because he had never obtained it in a state of purity.

‡ Ann. de Chim. xxxv. 161.

§ Ibid. lx. 79.

‖ Ibid. lxiv. 42.

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when dropped into acetate of lead. Pyrotartrate of potash is soluble in alcohol. It does not precipitate the salts of barytes and lime, as tartrate of potash does.*

SECT. XI.

OF PYROMUCIC ACID.

This acid was obtained by M. Houton Labillardiere, by distilling in a retort the acid called *saclactic* or *mucic* acid. The matter which comes over into the receiver is to be mixed with four times its weight of water, and then evaporated to the requisite degree. The pyromucic acid is deposited in crystals, and more crystals are obtained when the mother liquor is concentrated still farther.

Properties.

Pyromucic acid thus obtained melts at the temperature of 266°, and if the heat be continued, sublimes in the form of yellow crystals, which on being dissolved in water, and crystallized, become perfectly white and pure.

Pyromucic acid is white, has an acid taste, and is destitute of smell. It melts at 266°, and sublimes, condensing into a liquid which becomes solid on cooling. It does not deliquesce. It reddens vegetable blues. It is more soluble in hot than in cold water. Alcohol dissolves it more abundantly than water. Most of the salts which it forms are soluble and crystallizable. They have received the name of *pyromucates*. Pyromucate of barytes, according to the analysis of Houton Labillardiere, is composed as follows:

Acid	57·7	13·331
Barytes	42·2	9·75
	99·9	

According to this analysis, the equivalent number for this acid is 13·331.

Constituents.

When analysed by means of peroxide of copper, its constituents were found to be

Carbon	52·118
Oxygen	45·806
Hydrogen	2·111
	100·035

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* Ann. de Chim. lxiv. 42.

The number of atoms coming nearest to these proportions, and to the equivalent number for the acid, as indicated by the composition of pyromucate of barytes, is as follows:

9 atoms carbon	= 6·75	51·43
6 atoms oxygen	= 6	45·71
3 atoms hydrogen	= 0·375	2·86
	13·125	100·00

According to this the equivalent number for the acid is only 13·125, instead of 13·331. This deviation does not exceed 2 per cent. and may be allowed in a first analysis of a salt, which it must be difficult to free completely from its water of crystallization.*

SECT. XII.

OF OXALIC ACID.

History.

WHEN nitric acid is poured upon sugar, and a moderate heat applied, the sugar soon melts, an effervescence ensues, a great quantity of nitrous gas and carbonic acid gas is emitted; and when the effervescence ceases, and the liquid in the retort is allowed to cool, a number of small transparent crystals appear in it. These crystals constitute a peculiar acid, which has received the name of *oxalic acid*, because it exists ready formed, as Scheele has proved, in the *oxalis acetosella*, or wood-sorrel. At first, however, it was called the *acid of sugar*, or the *saccharine acid*.

As the earliest and best account of the oxalic acid was published by Bergman, he was for a long time reckoned the discoverer of it; but Mr. Ehrhart, one of Scheele's intimate friends, informs us, that the world is indebted for its knowledge of this acid to that illustrious chemist,† and Hermbstadt and Westrumb assign the discovery to the same author.‡ The assertions of these gentlemen, who had the best opportunity of obtaining accurate information, are certainly sufficient to establish the fact, that Scheele was the real discoverer of oxalic acid.

Preparation.

1. Bergman gives us the following process for obtaining

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* Ann. de Chim. et de Phys. ix. 365.

† Elwert's Magazine for Apothecaries, 1785, part i. p. 54.

‡ Keir's Dictionary.

this acid: "Put one ounce of white sugar powdered into a tubulated retort, with three ounces of strong nitric acid, the specific gravity of which is to that of water as 1·567 to 1. When the solution is over, during which many fumes of the nitrous acid escape, let a receiver be fitted, and the liquor made to boil, by which abundance of nitrous gas is expelled. When the liquor in the retort acquires a reddish-brown colour, add three ounces more of nitric acid, and continue the boiling till the fumes cease, and the colour of the liquor vanishes. Then let the contents of the retort be emptied into a wide vessel; and, upon cooling, a crystallization will take place of slender quadrilateral prisms, which are often affixed to each other at an angle of 45°. These crystals, collected and dried on blotting paper, will be found to weigh 1½ dr. 19 gr. By boiling the remaining lixivium with two ounces of nitric acid in the retort till the red fumes almost disappear, and by repeating the crystallization as before, ½ dr. 13 gr. of solid acid will be obtained. If the process be repeated once more upon the residuum, which has now a glutinous consistence, with the successive additions of small quantities of nitric acid, amounting in all to two ounces, a saline brown deliquescent mass will be formed, weighing half a dram, of which about a half will be lost by a farther purification. The crystals obtained thus at different times may be purified by solution and crystallization, and by digesting the last lixivium with some nitric acid, and evaporation with the heat of the sun."

By the same process Bergman obtained it from gum arabic, alcohol, and honey: Scheele, Hermbstadt, Westrumb, Hoffman, &c. from a great variety of other vegetable productions; and Berthollet from a great number of animal substances.

It is of great consequence not to use too much nitric acid, otherwise the quantity of oxalic acid will be diminished; and if a very great quantity of nitric acid be used, no oxalic acid will be obtained at all.* On the contrary, Hermbstadt affirms, that if too small a quantity of nitric acid be used, the acid obtained will not be the oxalic, but the tartaric. But I have not found this confirmed upon trying the experiment. 100 grains of sugar, when properly treated, yield 58 grains of crystallized oxalic acid.

Properties.

2. Oxalic acid, thus prepared, is in the form of four-sided prisms, whose sides are alternately larger, and they are ter-

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* Bergman.

minated at the extremities by two-sided summits. They are transparent, and of a fine white colour, with considerable lustre: they have a very acid taste, and redden vegetable blues. These crystals contain water and are in the state of a *hydrate.* When cautiously heated on a sand-bath they fall to powder and lose about a third of their weight; but in this case a portion of the acid is sublimed. Berzelius * has shown that they are composed of

Real acid	52	100
Water	48	92·3

Hence they seem to be a compound of 1 atom acid + 4 atoms water.

Action of heat.

3. When this crystallized acid is exposed to heat in an open vessel, there arises a smoke from it, which affects disagreeably the nose and lungs. The residuum is a powder of a much whiter colour than the acid had been. By this process it loses $\frac{1}{3}$d of its weight, but soon recovers it again on exposure to the air. When distilled, it first loses its water of crystallization, then liquefies and becomes brown; a little phlegm passes over, a white saline crust sublimes, some of which passes into the receiver; but the greatest part of the acid is destroyed, leaving in the retort a mass $\frac{1}{50}$th of the whole, which has an empyreumatic smell, blackens sulphuric acid, renders nitric acid yellow, and dissolves in muriatic acid without alteration. That part of the acid which sublimes is unaltered. When this acid is distilled a second time, it gives out a white smoke, which, condensing in the receiver, produces a colourless uncrystallizable acid, and a dark-coloured matter remains behind.† During all this distillation a vast quantity of elastic vapour makes its escape. From 279 grains of oxalic acid, Bergman obtained 109 cubic inches of gas, half of which was carbonic acid, and half carburetted hydrogen. Fontana from an ounce of it obtained 430 cubic inches of gas, one-third of which was carbonic acid, the rest carburetted hydrogen.

Of water.

4. The crystals of oxalic acid are soluble in their own weight of boiling water: water at the temperature of 65·7° dissolves half its weight of them. The specific gravity of the solution is 1·0593.‡ One hundred parts of boiling alcohol dissolve 56 parts of these crystals; but at a mean temperature only

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* Ann. de Chim. lxxxi. 300.

† Bergman.

‡ Ibid. i. 255.

40 parts.[*] Liquid oxalic acid has a very acrid taste when it is concentrated, but a very agreeable acid taste when sufficiently diluted with water.[†] When swallowed in considerable quantities, as to the amount of an ounce, it proves almost immediately fatal.

It changes all vegetables blues except indigo to a red. One grain of crystallized acid, dissolved in 1920 grains of water, reddens the blue paper with which sugar loaves are wrapped: one grain of it, dissolved in 3600 grains of water, reddens paper stained with turnsol.[‡] According to Morveau, 1 part of the crystallized acid is sufficient to communicate a sensible acidity to 2633 parts of water.[§]

Its fixity is such, that none of it is sublimed when water containing it in solution is raised to the boiling temperature.

Of simple bodies.

5. Oxalic acid is not affected by exposure to the air, or to the action of oxygen gas. The effect of the simple combustibles on it has not been tried; but in all probability it is inconsiderable.

It is capable of oxidizing lead, copper, iron, tin, bismuth, nickel, cobalt, zinc, manganese.

It does not act upon gold, silver, platinum, mercury.

6. Oxalic acid combines with alkalies, earths, and metallic oxides, and forms salts known by the name of *oxalates.*

7. Muriatic and acetic acids dissolve oxalic acid, but without altering it.[||] Sulphuric acid partly decomposes it by the assistance of heat, and a quantity of charcoal is formed. Nitric acid decomposes it at a boiling heat, and converts it into water and carbonic acid.[**] From this result, and from the products obtained by distilling pure oxalic acid, it follows, that this acid is composed of oxygen, hydrogen, and carbon.

Decomposition.

When the dry oxalates are exposed to a red heat the oxalic acid is completely decomposed. So far as my experiments have gone, the oxalic acid is decomposed precisely in the same way, and the same new products formed whatever oxalate we use; but the oxalate of lime is most convenient, because we can ascertain its composition with the greatest accuracy. When oxalate of lime is distilled in a small retort by means of a heat gradually raised to redness, the oxalic acid is completely decomposed and converted into five new substances;

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[*] Bergman, i. 255. [†] Ibid. [‡] Ibid.

[§] Encyc. Method. art. Acide Saccharin.

[||] Bergman. [**] Fourcroy, vii. 224.

namely, *water, carbonic acid, carbonic oxide, carburetted hydrogen, and charcoal.* The water is small in quantity, the carbonic acid large, and partly in the state of gas, partly combined with the base of the oxalate. The carbonic oxide and carburetted hydrogen are in the state of gases, and in the proportion of about 2⅓ of the former to 1 of the latter. The charcoal is small in quantity, and mixed with the residue in the retort, to which it gives a grey colour. By carefully ascertaining the proportion of each of these products, and estimating their composition according to the most exact analyses hitherto made of each, I found that the composition of oxalic acid may be stated as follows:

Composition.

Oxygen	64
Carbon	32
Hydrogen	4
	100

It has been lately analysed by Gay-Lussac and Thenard,* and by Berzelius.† The results which they obtained are as follows:

	Hydrogen.		Carbon.		Oxygen.
Gay-Lussac	2·745	+	26·566	+	70·689
Berzelius	0·244	+	33·222	+	66·534

If we consider the experiments of Berzelius as exact, it follows that oxalic acid is composed as follows:

Hydrogen $\frac{1}{12}$ of an atom = 0·0104
Carbon 2 atoms = 1·5
Oxygen 3 atoms = 3·

4·5104

The constitution of oxalate of lead, as determined by Berzelius, agrees very well with this result. According to him it is composed of

Oxalic acid	100	4·552
Oxide of lead	307·5	14·000

The equivalent for oxalic acid we perceive is 4·552, which differs very little from 4·5104, the number derived from the analysis of oxalic acid.

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* Recherches Physico-chimiques, ii. 302.

† Annals of Philosophy, v. 99.

I am disposed to consider the hydrogen detected in the analysis of this salt by all the experimenters, to be derived from a portion of water of which it had been impossible to deprive the acid. For the proportion of hydrogen diminishes in proportion to the care taken to dry the salt used before it is subjected to decomposition. Accordingly the quantity of hydrogen found by Berzelius, who was at the greatest pains to dry his salt before analysis, amounts only to $\frac{1}{12}$th of an atom, a quantity so insignificant, that we cannot suppose it to enter as a real constituent of the acid. But if the acid be destitute of hydrogen, it is obvious that it is a compound of 1 part by weight of carbon and 2 parts of oxygen, or of 2 atoms carbon + 3 atoms oxygen, or of an integrant particle of carbonic acid and an integrant particle of carbonic oxide. Hence the true equivalent number for it must be 4·5.

SECT. XIII.

OF MELLITIC ACID.

History.

THERE is a mineral of a honey-yellow colour which is found in small solitary crystals among the layers of Wood-coal at Arten in Thuringia. At first sight it has some resemblance to amber; but Werner recognised it as a peculiar substance about the year 1790, and gave it the name of *honigstein* (honey-stone), which foreign mineralogists converted into *mellite*. This mineral is very rare. Hitherto indeed it has been found only in Thuringia and in Switzerland.*

Mellite has usually a honey-yellow colour, but sometimes a straw-yellow. It is always crystallized in octahedrons, but they are rarely entire; sometimes indeed almost the whole of one of the pyramids is wanting. Their surface is generally smooth and brilliant, and interiorly they have a glassy lustre. They are semitransparent, brittle, soft, and easily reduced to powder. When pounded, they assume a yellowish-grey colour. Their specific gravity is about 1·550.†

Mineralogists soon discovered that mellite is partly combustible; but they did not agree about its component parts. Lampadius ‡ and Abich § undertook its chemical analysis about the same time.

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* Brochant's Mineralogy, ii. 75.

† Klaproth's Beitrage, iii. 115.

‡ Crell's Annals, 1797, ii. 10.

§ Crell's Annals, 1797, p. 16.

But the results of their analyses differed so much from each other, that little confidence could be placed in either. Besides, it was evident from the way in which their experiments were conducted, that the original component parts of mellite had been altered by fire. Klaproth analysed it in 1799, and ascertained it to be a compound of alumina and a peculiar acid, to which he gave the name of *mellitic.*[*] And this analysis was soon after confirmed by Mr. Vauquelin.[†]

Preparation.

1. Hitherto mellitic acid has been found only in the mellite. It may be procured from that mineral by the following process: reduce the mellite to powder, and boil it in about 72 times its weight of water. The acid combines with the water, and the alumina separates in flakes. By filtering the solution, and evaporating sufficiently, the mellitic acid is obtained in the state of crystals.

Properties.

2. These crystals are either very fine needles, sometimes collected into globules, or small short prisms. They have a brownish colour, and a taste at first sweetish-sour, and afterwards bitterish.

3. This acid is not very soluble in water; but the precise degree of solubility has not been ascertained.

4. When exposed to heat, it is readily decomposed, exhaling an abundant smoke, which however is destitute of smell. A small quantity of insipid ashes remain behind, which do not alter the colour of litmus paper.

5. All attempts to convert it into oxalic acid by the action of nitric acid have failed. The nitric acid merely caused it to assume a straw-yellow colour.

6. The effect of the simple bodies on this acid has not been tried.

7. It combines with alkalies, earths, and metallic oxides, and forms with them salts which are distinguished by the name of *mellates.* The properties of these compounds will be considered afterwards.

8. From the analysis of Mr. Klaproth, we learn that the mellite is composed of

46	mellitic acid
16	alumina
38	water
100	

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[*] Beitrage, iii. 111.

[†] Ann. de Chim. xxxvi. 203.

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Now when mellite is distilled in a retort, the acid is completely decomposed, and its elements combine together in a different way. By this method Mr. Klaproth obtained from 100 grains of mellite

54 cubic inches of carbonic acid gas
13 .... hydrogen gas
38 grains of acidulous and aromatic water
1 ....aromatic oil
9 ....charcoal
16 ....alumina

From this analysis it is obvious, that mellitic acid is composed of carbon, hydrogen, and oxygen, like most of the combustible acids.

Composition.

Though these data are not sufficiently precise to enable us to determine the constituents of this acid with precision, they will furnish at least an approximation. If we suppose Klaproth's analysis of mellite to be correct, it follows from it that the equivalent number for mellitic acid is 6·102. For 16 : 46 :: 2·125 : 6·102. Let us suppose 6·125 to represent the weight of an atom of mellitic acid. This may be made up of the following atoms:

1 atom hydrogen = 0·125
4 atoms carbon = 3·000
3 atoms oxygen = 3·000

According to this supposition 100 parts of it would consist of

Hydrogen	2·04
Carbon	48·98
Oxygen	48·98
	100·00

Now (neglecting the 38 grains of acidulous water) Klaproth's analysis gives us the constituents as follows:

Hydrogen	0·35
Carbon	47·11
Oxygen	52·54
	100·00

If we consider the imperfection of the data, we must admit that this affords as near a coincidence with the preceding numbers as could be expected.

SECT. XIV.

OF TARTARIC ACID.

Subdivis. I. Chap. III.

History.

TARTAR, OR CREAM OF TARTAR, as it is commonly called, when pure, has occupied the attention of chemists for several centuries. Duhamel and Grosse, and after them Margraff and Rouelle the younger, proved that it was composed of an acid united to potash; but Scheele was the first who obtained this acid in a separate state. He communicated his process for obtaining it to Retzius, who published it in the Stockholm Transactions for 1770. It consisted in boiling tartar with chalk, and in decomposing the tartrate of lime thus formed by means of sulphuric acid.

Preparation.

1. The process employed at present for obtaining tartaric acid, which is the same with that of Scheele, is the following: dissolve tartar in boiling water, and add to the solution powdered chalk till all effervescence ceases, and the liquid does not redden vegetable blues. Let the liquid cool, and then pass it through a filter. A quantity of tartrate of lime (which is an insoluble white powder) remains upon the filter. Put this tartrate, previously well washed, into a glass cucurbite, and pour on it a quantity of sulphuric acid equal to the weight of the chalk employed, which must be diluted with water. Allow it to digest for 12 hours, stirring it occasionally. The sulphuric acid displaces the tartaric: sulphate of lime remains at the bottom, while the tartaric acid is dissolved in the liquid part. Decant off this last, and try whether it contains any sulphuric acid. This is done by dropping in a little acetate of lead; a precipitate appears, which is insoluble in acetic acid if sulphuric acid be present, but soluble if it be absent. If sulphuric acid be present, the liquid must be digested again on some more tartrate of lime; if not, it is to be slowly evaporated, and about one-third part of the weight of the tartar employed is obtained of crystallized tartaric acid.

Lime may be substituted for chalk in this process. In that case the decomposition of the tartar is complete; whereas by Scheele's method, the excess of acid only combines with the chalk; but when lime is used, the whole tartrate of lime by no means separates. A considerable portion is retained in solution by the potash of the tartar now disengaged. If the liquid be evaporated, this portion appears under the form of a transparent jelly. By exposure to the air the potash attracts carbonic acid, which unites to the lime, while the tartaric acid combines again with the potash. To obtain the potash in a state of tolerable purity, the best method, according to Vauquelin, to whom we are indebted for these observations, is to evaporate to dryness, and heat the residue to redness. By lixiviating the mass, the potash will be obtained in a state of considerable purity.*

Crystals. 2. Tartaric acid, according to my observations, crystallizes in four-sided prisms, apparently rectangular and terminated by dihedral summits. Sometimes the prisms terminate in four-sided pyramids. Sometimes the crystals assume the form of triangular plates. Their specific gravity is 1·5962.†

As they are sold by apothecaries in this country, they are in groups, and appear to be very irregular four-sided prisms.

3. Crystallized tartaric acid is white, and very firm, and is but imperfectly transparent. It may be exposed to the air for any length of time without undergoing any change. When heated a few degrees above 212° it melts and remains limpid and transparent like water. At 250° it boils without losing its transparency or becoming coloured. If the boiling be continued for a short time only it does not lose above 4 per cent. of its weight. On cooling it concretes again into a hard semitransparent mass, very much resembling a quantity of white sugar that has been melted at the same temperature. By this process the nature of the acid is changed. It now deliquesces when exposed to the air.

Tartaric acid, in its ordinary crystallized state, is a hydrate composed, according to the experiments of Berzelius,‡ of

Real acid	100
Water	12·7

Or 100 of the crystals contain 88·5 of real acid.

Hence it seems to be a compound of 1 atom acid + 1 atom water. On that supposition its real composition ought to be

Real acid	100
Water	13·43

When tartaric acid combined with a base, as with lime, is distilled in a sufficiently strong heat, it is completely decom-

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* Ann. de Chim. xlvii. 147.

† Hassenfratz, Ann. de Chim. xxxviii. 11.

‡ Ann. de Chim. lxxxi. 295.

posed. The products into which it is converted, are *water*, *carbonic acid*, *heavy inflammable air*, *oil*, and *charcoal*. The quantity of carbonic acid which it yields is less than what is furnished by an equal weight of oxalic acid; but it differs from oxalic acid, in yielding a portion of brown-coloured thick oil, which has an empyreumatic smell, and dissolves in alcohol.

4. Tartaric acid dissolves readily in water. Bergman obtained a solution, the specific gravity of which was 1·230.[*] Morveau observed, however, that crystals formed spontaneously in a solution, the specific gravity of which was 1·084. It is not liable to spontaneous decomposition when dissolved in water, unless the solution be considerably diluted.

Action of simple bodies.

5. Neither its action on simple supporters nor combustibles has been examined; but it is probable that it is not capable of producing any sensible change on them. It oxidizes iron and zinc, and even mercury; but it does not act upon antimony, bismuth, tin, lead, copper, silver, gold, nor platinum. Its action on the other metallic bodies has scarcely been examined.

6. It combines with alkalies, earths, and metallic oxides, and forms salts known by the name of *tartrates*. Though it forms with the alkaline earths salts which are scarcely soluble in water, yet it has not the property of precipitating any of them from their solutions. In this respect it differs very greatly from oxalic acid, which precipitates them all except magnesia.

Composition.

7. This acid has been lately analysed by Gay-Lussac and Thenard,[†] and Berzelius.[‡] The following table exhibits the results which they obtained:

	Hydrogen.		Carbon.		Oxygen.
Gay-Lussac	6·629	+	24·050	+	69·321
Berzelius	3·951	+	36·167	+	59·882

Berzelius has shown that the tartaric acid of Gay-Lussac and Thenard contained, in fact, 34·54 per cent. of water, and that their analysis, when this quantity is subtracted, agrees very nearly with his. It follows, from the numbers of Berzelius, that the constitution of tartaric acid is as follows:

3 atoms hydrogen = 0·375
4 atoms carbon = 3·000
5 atoms oxygen = 5·000

8·375

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[*] Bergman, i. 250.

[†] Recherches Physico-chimiques, ii. 304.

[‡] Annals of Philosophy, v. 96.

An integrant particle of it, according to this constitution, will weigh 8·375. Now this corresponds very well with the weight of an atom of tartaric acid, as deduced from the composition of tartrate of lead. This salt, according to the analysis of Berzelius, is composed of

Tartaric acid	100	8·383
Oxide of lead	167	14

The number 8·383 derived from this salt, agrees very nearly with the number 8·375, deduced from the analysis of tartaric acid.

Tartaric acid, in a state of purity, has scarcely been put to any use; but some of the compounds into which it enters are much employed in medicine. This acid has the property of combining in two different proportions with a great number of bases. With potash, for instance, in one proportion, it forms a salt pretty soluble in water, called *tartrate of potash;* but when added in a greater proportion, it forms *tartar*, a salt very imperfectly soluble in water. By this property, the presence of tartaric acid in any acid solution may easily be detected. All that is necessary is to drop in slowly a little solution of potash: if tartaric acid be present, tartar immediately precipitates in the form of a white gritty powder.

SECT. XV.

OF CITRIC ACID.

History.

CHEMISTS have always considered the juice of oranges and lemons as an acid. This juice contains a quantity of mucilage and water, which renders the acid impure, and subject to spontaneous decomposition. Mr. Georgi took the following method to separate the mucilage. He filled a bottle entirely with lemon-juice, corked it, and placed it in a cellar: in four years the liquid was become as limpid as water, a quantity of mucilage had fallen to the bottom in the form of flakes, and a thick crust had formed under the cork. He exposed this acid to a cold of of 23°, which froze a great part of the water, and left behind a strong and pretty pure acid.* It was Scheele, however, that first pointed out a method of obtaining this acid perfectly pure, and who demonstrated that it possesses peculiar properties.

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* Kongl. Vetenskaps Academiens Handlingar for 1774, p. 245.

Preparation.

1. His process, which is still followed, is this: Saturate lemon juice, while boiling, with powdered chalk. A white powder falls to the bottom, which is lime combined with citric acid. Separate this powder, and wash it with warm water till the water passes off colourless. Then pour upon it as much sulphuric acid as will saturate the chalk employed, having previously diluted it with six times its weight of water. Boil the mixture for some minutes, and pass it through a filter to separate the sulphate of lime. The liquid is then to be evaporated to the consistence of a syrup, and set aside to cool. A number of crystals form in it: these are *citric acid.**

Mr. Scheele advises the use of an excess of sulphuric acid in order to ensure the separation of all the lime: but according to Dizé, this excess is necessary for another purpose.† A quantity of mucilage, he thinks, still adheres to the citric acid in its combination with lime, and sulphuric acid is necessary to decompose this mucilage.

Proust, who has published a memoir on the preparation of citric acid in the Journal de Physique for 1801,‡ has shown that when too much sulphuric acid is employed, it acts upon the citric acid, chars it, and prevents it from crystallizing. This error is remedied by adding a little chalk. This chemist has ascertained, that four parts of chalk require for saturation 94 parts of lemon juice. The citrate of lime obtained amounts to 7½ parts. To decompose this, 20 parts of sulphuric acid, of the specific gravity 1·15, are necessary.

Properties.

2. The crystals of citric acid are rhomboidal prisms, the sides of which are inclined to each other at angles of about 120 and 60 degrees, terminated at each end by four trapezoidal faces, which include the solid angles.§ They are not altered by exposure to the air. Their taste is exceedingly acid, and even excites pain; but when the acid is properly diluted with water, the acidity is pleasant. These crystals contain combined water; and, therefore, are in the state of a hydrate. According to the analysis of Berzelius,|| they are composed of

Real acid	100
Water	26·58

This approaches 1 atom acid + 2 atoms water. Had the

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* Scheele, ii. 203.

† Nicholson's Journal, ii. 43.

‡ Jour. de Phys. lii. 366.

§ Dizé, Nicholson's Journal, ii. 33.

|| Ann. de Chim. lxxxii. 297.

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water amounted to 30·5, instead of 26·58, it would have been exactly 2 atoms. 100 of the crystals contain 79 real acid.

3. When this acid is exposed to a heat sufficiently strong to melt it, and kept in that temperature till it falls down into a white powder, it loses about 7 per cent. or very nearly $\frac{1}{3}$ of its water. When exposed to the open fire, it first melts, then swells up and exhales an acrid vapour, and leaves behind it a small quantity of charcoal. When distilled in close vessels, it partly evaporates without decomposition, and is partly converted into acetic acid, carbonic acid, and carburetted hydrogen gas, which pass over, and charcoal which remains in the retort.

4. Citric acid is exceedingly soluble in water. According to Vauquelin, 100 parts of it require only 75 parts of water. Boiling water dissolves twice its weight of it.* This solution may be kept a long time in close vessels; however it at last putrifies, and is decomposed.

5. Neither oxygen gas nor the simple combustibles or incombustibles produce any effect upon it. It is capable of oxidizing iron, zinc, tin. It does not act upon gold, silver, platinum, mercury, bismuth, antimony, arsenic.

6. It combines with alkalies, earths, and metallic oxides, and forms salts known by the name of *citrates*.

Action of acids.

7. The action of none of the acids on it has been examined, if we except that of the sulphuric and nitric. Sulphuric acid, when concentrated, converts it into acetic acid.† Scheele said that he could not convert it into oxalic acid by means of nitric acid, as he had done several other acids: but Westrumb affirms, that this conversion may be affected; and thinks that Scheele had probably failed from having used too large a quantity of nitric acid, by which he had proceeded beyond the conversion into oxalic acid, and had changed the citric acid into vinegar: and in support of his opinion, he quotes his own experiments; from which it appeared that, by treating 60 grains of citric acid with different quantities of nitric acid, his products were very different. Thus with 200 grains of nitric acid he got 30 grains of oxalic acid; with 300 grains of nitric acid he obtained only 15 grains of the oxalic acid; and with 600 grains of nitric acid no vestige appeared of the oxalic acid. On distilling the products of these experiments, especially of

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* Dizé.

† Fourcroy, vii. 206.

the last, he obtained vinegar mixed with nitric acid. The experiments of Westrumb have been confirmed by Fourcroy and Vauquelin; who, by treating citric acid with a great quantity of nitric acid, converted it into oxalic and acetic acids. The proportion of the first was much smaller than that of the second.

Composition.

8. Citric acid has been analyzed with much precision by Gay-Lussac and Thenard,* and Berzelius.† The following table exhibits the results which they obtained:

	Hydrogen.		Carbon.		Oxygen.
Gay-Lussac	6·330	+	33·811	+	59·859
Berzelius	3·800	+	41·369	+	54·831

If we take Berzelius' numbers as affording the nearest approximation to accuracy, we may consider the constitution of citric acid as the following:

3 atoms hydrogen .... = 0·375‡
4 atoms carbon ...... = 3·000
4 atoms oxygen ...... = 4·000

7·375

According to this constitution the weight of an integrant particle of citric acid is 7·375. This corresponds very well with the equivalent number for citric acid derived from the composition of citrate of lead. This salt, according to the analysis of Berzelius, is composed of

Citric acid	100	7·368
Oxide of lead	190	14

The difference between 7·375 and 7·368 is very small.

SECT. XVI.

OF KINIC ACID.

Discovery.

Mr. Deschamps, junior, an apothecary in Lyons, some

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* Recherches Physico-chimiques, ii. 307.

† Annals of Philosophy, v. 93.

‡ The analysis of Berzelius only indicates two atoms. But I have preferred three, partly on account of the greater proportion of hydrogen obtained by Gay-Lussac and Thenard, and partly because it makes the weight agree better with the equivalent number for the acid derived from the composition of citrate of lead.

time ago published a method of extracting from yellow Peruvian bark a peculiar salt, to which the physicians of Lyons ascribed the febrifuge properties of that bark. His process was very simple; the bark was macerated in cold water, and the infusion concentrated by evaporation. It was then set aside for some time in an open vessel. The crystals of the salt gradually formed and separated, and they were purified by repeated crystallizations. From 100 parts of the bark about 7 parts of these crystals were obtained.*

This salt has been lately examined by M. Vauquelin, who has proved that it is composed of lime united to a peculiar acid hitherto unknown. To this acid he has given the name *kinic*, borrowed from the term *quinquina*, applied by the French writers to the bark from which the salt was extracted.

Kinate of lime.

Deschamp's salt then is *kinate of lime.* It possesses the following properties.

Its colour is white, it crystallizes in square or rhomboidal plates; it has no taste, and is flexible under the teeth. It dissolves in about five times its weight of water at the temperature of 55°. It is insoluble in alcohol.

When placed on burning coals it swells, gives out a smell like tartar, and leaves a mixture of carbonate of lime and charcoal. The fixed alkalies and their carbonates precipitate lime from the solution of this salt, but ammonia produces no effect. Sulphuric and oxalic acid precipitate lime likewise, but no precipitate is produced by acetate of lead or nitrate of silver. The infusion of tannin occasions a flaky yellow precipitate.

Separation of kinic acid.

M. Vauquelin separated the lime from the kinic acid by means of oxalic acid. The oxalate of lime obtained from 100 grains of the salt weighed 27 grains. Hence he concluded that the salt was a compound of 85 parts acid and 15 lime. But the lime in 27 grains of oxalate of lime very little exceeds 10 grains. Hence the salt ought to be composed of 90 parts acid and 10 of lime.

Properties.

The kinic acid, thus freed from lime, was concentrated by evaporation to the consistency of a syrup, and then set aside for a week. No crystals formed in it spontaneously; but upon being touched with a glass rod it wholly crystallized at once in divergent plates.

Its colour was slightly brown (doubtless from some impu-

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* Ann. de Chim. xlviii. 162.

rity,) its taste was extremely acid and somewhat bitter, probably because it was not quite free from the other constituents of the bark. It was not altered by being left exposed to the air.

On burning coals it melted, frothed, blackened, and exhaled in acrid vapours, leaving only a little charcoal behind.

It combines with the different bases, and forms a set of salts called *kinates*. The alkaline and earthy kinates are soluble and crystallizable. This acid does not precipitate nitrates of silver, mercury, nor lead.*

This detail, though imperfect, is sufficient to distinguish the kinic from every other acid. Its decomposition by heat shows that it belongs to the class of combustible acids. Its crystallizing, its great solubility in water, and its forming a soluble salt with lime, and not precipitating silver nor lead, sufficiently distinguish it from all the other combustible acids with which it might be confounded.

SECT. XVII.

OF SACLACTIC OR MUCIC ACID.

History.

This acid was discovered by Scheele in 1780. After having obtained oxalic acid from sugar, he wished to examine whether the sugar of milk would furnish the same product. Upon four ounces of pure sugar of milk, finely powdered, he poured 12 ounces of diluted nitric acid, and put the mixture in a large glass retort, which he placed in a sand-bath. A violent effervescence ensuing, he was obliged to remove the retort from the sand-bath till the commotion ceased. He then continued the distillation till the mixture became yellow. As no crystals appeared in the liquor remaining in the retort after standing two days, he repeated the distillation as before, with the addition of eight ounces of nitric acid, and continued the operation till the yellow colour, which had disappeared on the addition of the nitric acid, returned. The liquor in the retort contained a white powder, and when cold was observed to be thick. Eight ounces of water were added to dilute this liquor, which was then filtrated, by which the white powder was separated; which being edulcorated and dried, weighed 7½ dr. The filtrated solution was evaporated to the

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* Ann. de Chim. lix. 162.

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consistence of a syrup, and again subjected to distillation, with four ounces of nitric acid as before; after which, the liquor, when cold, was observed to contain many small, oblong, sour crystals, together with some white powder. This powder being separated, the liquor was again distilled with more nitric acid as before; by which means the liquor was rendered capable of yielding crystals again; and by one distillation more, with more nitric acid, the whole of the liquor was converted into crystals. These crystals, added together, weighed five drams; and were found, upon trial, to have the properties of the oxalic acid.

Mr. Scheele next examined the properties of the white powder, and found it to be an acid of a peculiar nature; he therefore called it the *acid of the sugar of milk.*[*] It was afterwards called *saclactic* acid by the French chemists. Fourcroy changed that name into that of *mucous acid*, because it is obtained by treating gum arabic, and other mucilaginous substances, with nitric acid. And this name has been since altered to that of mucic acid.

Preparation.

1. Saclactic acid may be obtained by the following process: upon one part of gum arabic, or other similar gum, previously put into a retort, pour two parts of nitric acid. Apply a slight heat for a short time, till a little nitrous gas and carbonic acid gas comes over; then allow the mixture to cool. A white powder gradually precipitates, which may be easily separated by filtration. This powder is saclactic acid.[†] It is not however pure, being mixed with a considerable portion of oxalate of lime, and with about 6 per cent. of a substance which is probably a compound of gum and lime. The oxalate of lime may be saperated by digesting the white powder repeatedly in diluted nitric acid. The gummate of lime is separated by dissolving the residual saclactic acid in boiling water, the gummate being insoluble in that liquid. The water on cooling deposites saclactic acid in a state of purity.[‡] If sugar of milk be employed instead of gum, the saclactic acid is obtained at once in a state of purity.

Properties.

2. Saclactic acid, thus obtained, is under the form of a white gritty powder, with a slightly acid taste.

Heat decomposes it. When distilled, there comes over an acid liquor which crystallizes in needles on cooling, containing

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[*] Scheele, ii. 69.

[†] Fourcroy, vii. 146.

[‡] Laugier; Ann. de Chim. lxxii. 81.

pyromucic acid, a red coloured acrid oil, carbonic acid gas, and carburetted hydrogen gas. There remains in the retort a large proportion of charcoal. According to Trommsdorf, an acid in crystals is also obtained which possesses the properties of succinic acid.*

Saclactic acid, according to Scheele, is soluble in 60 parts of its weight of boiling water; but Messrs. Hermbstadt† and Morveau‡ found, that boiling water only dissolved $\frac{1}{80}$th part: it deposited about $\frac{1}{4}$th part on cooling in the form of crystals.§

The solution has an acid taste, and reddens the infusion of turnsol.|| Its specific gravity, at the temperature of 53·7°, is 1·0015.**

The compounds which it forms with earths, alkalies, and metallic oxides, are denominated *saclactates.* These salts are but very imperfectly known, few chemists having examined them except Scheele. The facts which he ascertained are the following:

With potash it forms a salt soluble in eight parts of boiling water, which crystallizes on cooling. The saclactate of soda also crystallizes, and is soluble in five parts of water. Saclactate of ammonia loses its base by a moderate heat, while the acid remains behind. The compounds which it forms with the earths are nearly insoluble in water. It scarcely acts upon any of the metals, but it combines with their oxides: it forms salts almost insoluble in water. When poured into the nitrates of silver, mercury, or lead, it occasions a white precipitate. It produces no change on the sulphates of iron, copper, zinc, manganese, nor on the muriates of tin and mercury.††

Composition.

This acid has been analyzed with much precision by Gay-Lussac and Thenard,‡‡ and by Berzelius.§§ The following table exhibits the result of their experiments:

	Hydrogen.		Carbon.		Oxygen.		
Gay-Lussac....	3·62	+	33·69	+	62·69	=	100
Berzelius......	5·105	+	33·430	+	61·465	=	100

If we take the numbers of Berzelius as furnishing the

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* Ann. de Chim. lxxi. 79.

† Phys. Chem.

‡ Encyc. Method. i. 290.

§ Scheele.

|| Scheele.

** Morveau, ibid.

†† Scheele, ii. 76.

‡‡ Recherches Physico-chimiques, ii. 298.

§§ Annals of Philosophy, v. 179.

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nearest approximation to the truth, they will give us the constitution of saclactic acid as follows:

5 atoms hydrogen	= 0·625
6 atoms carbon	= 4·5
8 atoms oxygen	= 8·
	13·125

The composition of saclactate of lead, as determined by the analysis of Berzelius, corresponds very well with this weight of an integrant particle of saclactic acid. According to him, saclactate of lead is composed as follows:

Saclactic acid	100	.... 13·1
Oxide of lead	106·87	 14

The equivalent number for saclactic acid given by this analysis, which is 13·1, almost coincides with 13·125, the number derived from the analysis of saclactic acid.

SECT. XVIII.

OF URIC ACID.

Discovery.

VARIOUS attempts were made by chemists to ascertain the nature of the calculous concretions which occasionally form in the kidneys and bladder, and produce one of the most painful diseases to which we are liable. These attempts were attended with very little success, till Scheele published a set of experiments on the subject in 1776. He examined several of these urinary calculi, and found them composed chiefly of a peculiar acid, the properties of which he described. His results were soon after confirmed by Bergman, who had engaged in a similar set of experiments about the same time.* To the acid thus discovered, Morveau gave at first the name of *bezoardic*, which was afterwards changed into *lithic* by the French chemists, when they contrived the new chemical nomenclature in 1787. This last term, in consequence chiefly of the observations and objections of Dr. Pearson, was afterwards laid aside, and the name *uric acid* substituted in its place.

Scheele ascertained that uric acid exists always in human urine. Experiments on the urinary calculi were published by

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* Scheele, i. 199 and 210. French Trans.

Mr. Higgins in 1789,* and by Dr. Austin in 1791; but little was added to our knowledge of uric acid till Dr. Wollaston published his admirable paper on the calculous concretions in 1797. Dr. Pearson published a copious set of experiments on the same subject in 1798, in which he enumerates his trials on uric acid, and endeavours to prove that it is not entitled to the name of acid, but ought to be classed among animal oxides. This drew the attention of Fourcroy and Vauquelin to the subject: they published an excellent treatise on urinary calculi, in which they demonstrate that it possesses the properties of an acid, and confirm the observations of Bergman and Scheele. But for the most complete account of uric acid we are indebted to Dr. Henry, who made it the subject of his thesis published in 1807, and afterwards inserted a paper on it in the second volume of the new series of Manchester Memoirs.

Preparation.

1. To obtain pure uric acid, Dr. Henry dissolved pulverised calculi (previously known to be composed chiefly of that acid) in a ley of potash, and precipitated the uric acid by means of muriatic acid or acetic acids. The powder thus obtained was first washed with a little ammonia, to remove any adhering foreign acid, and then edulcorated with a sufficient quantity of warm water.

Properties.

2. Uric acid thus obtained is a white powder, which feels harsh but not gritty, and is destitute of both taste and smell. It reddens the infusion of litmus. It dissolves in 1720 parts of water at the temperature of 60°, and in 1150 parts of boiling water. As this last solution cools, it deposites minute crystals of uric acid. The watery solution reddens litmus, but produces no precipitate when dropped into earthy or metallic salts.†

3. It is rapidly dissolved by fixed alkaline solutions, but less readily by ammonia. The alkaline carbonates have no effect on it whatever.‡

4. It decomposes the alkaline hydrosulphurets, and precipitates their sulphur. It likewise decomposes soap, provided a sufficient quantity of it be employed.§

5. It dissolves in nitric acid; and when the solution is evaporated nearly to dryness, it assumes a fine pink colour, which becomes much deeper when water is added, so as to have a

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* Comparative view of the phlogistic and antiphlogistic theories, p. 283.

† Henry.

‡ Scheele, Fourcroy, and Henry.

§ Henry.

near resemblance to carmine. In this state it stains wood, the skin, &c. of a beautiful red colour. The watery solution of this matter loses its red colour in a few hours, and it cannot afterwards be restored.*

When the solution of uric acid in nitric acid is boiled, a quantity of azotic gas, carbonic acid gas, and of prussic acid, is disengaged.† Dr. Pearson, by repeated distillations, converted the residue into nitrate of ammonia. When chlorine gas is made to pass into water containing this acid suspended in it, the acid assumes a gelatinous appearance, then dissolves; carbonic acid gas is emitted, and the solution yields by evaporation muriate of ammonia, superoxalate of ammonia, muriatic acid, and malic acid.‡

6. It combines with the different bases, and forms a genus of salts called *urates;* for the examination of which we are chiefly indebted to Dr. Henry.

7. When uric acid is distilled, about a fourth of the acid passes over altered in its properties, and is found in the receiver crystallized in plates; a few drops of thick oil make their appearance; $\frac{1}{8}$th of the acid, of concrete carbonate of ammonia; some prussiate of ammonia, some water, and carbonic acid pass over; and there remains in the retort charcoal, amounting to about $\frac{1}{8}$th of the weight of the acid distilled.§ According to Dr. Henry, the decomposition goes on in the following manner: 1. A drop or two of water holding carbonate of ammonia in solution passes into the receiver; 2. Dry carbonate of ammonia; 3. The acid sublimate; 4. The coal in the retort amounts to about $\frac{1}{6}$th of the calculus distilled.

Sublimate from uric acid.

The nature of the acid sublimate has been particularly examined by Dr. William Henry. Scheele had considered it as analogous to succinic acid, and Dr. Pearson as approaching to benzoic acid in its properties. According to Dr. Henry, it is a salt composed of a peculiar acid combined with ammonia. The following he found to be its properties.

Its colour is yellow, and it has a cooling bitter taste. It dissolves readily in water, and in alkaline solutions, from which it is not precipitated by acids. It dissolves also sparingly in alcohol. It is volatile; and when sublimed a second

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* Scheele, Bergman, Pearson, and Henry.

† Fourcroy, Ann. de Chim. xxvii. 267.

‡ Brugnatelli, Ann. de Chim. xxvii. 267. Fourcroy, x. 222.

§ Fourcroy, Ann. de Chim. xvi. 116.

time, becomes much whiter. The watery solution reddens vegetable blues; but a very small addition of ammonia destroys this property. It does not produce an effervescence with alkaline carbonates. By evaporation it yields permanent crystals, but ill defined, from a portion of animal matter adhering. They redden vegetable blues. Potash, when added to these crystals, disengages ammonia. When dissolved in nitric acid they do not leave a red stain as happens with uric acid; nor does their solution in water decompose the earthy salts, as happens with the alkaline urates: neither has it any action on the salts of copper, iron, gold, platinum, tin, or mercury. With nitrates of silver and mercury, and acetate of lead, it forms a white precipitate soluble in an excess of nitric acid. Muriatic acid occasions no precipitate in the solution of these crystals in water. These properties show us, that the acid of the sublimate is different from the uric, and from every other known acid. Dr. Austin found, that by repeated distillations it was resolved into ammonia, azote, and prussic acid. Hence its constituents are, doubtless, the same as those of uric acid, varying only in proportion.

Dr. Prout, who analyzed uric acid with great care by means of peroxide of copper, found its constituents as follows:

1 atom hydrogen . . . . = 0·125
3 atoms carbon . . . . . = 2·250
1 atom azote . . . . = 1·750
1½ atom oxygen . . . . = 1·500

5·625

According to this analysis the equivalent number for uric acid is 5·625. If we were to double the number of atoms in it in order to get rid of the half atom of oxygen the equivalent number for the acid would be 11·25. Which of these numbers is the true one can only be known by subjecting some of the urates to a careful analysis, which no person has hitherto done.

SECT. XIX.

OF PURPURIC ACID.

This acid was discovered by Dr. Prout, in the year 1818, while engaged in examining the pink-coloured substance

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formed by heating a solution of uric acid in nitric acid. This mode of obtaining the acid was as follows:

He digested pure uric acid in dilute nitric acid. An effervescence took place, and the acid was dissolved. The excess of nitric acid was neutralized by ammonia, and the evaporation continued. The colour of the liquid became gradually of a deeper purple and dark red granular crystals, (sometimes of a greenish hue externally), soon began to separate in abundance. These crystals were composed of purpuric acid and ammonia; they were dissolved in a solution of caustic potash, and heat applied to the solution till the red colour entirely disappeared. The alkaline solution was then gradually dropped into dilute sulphuric acid, which, uniting with the potash, left the acid principle in a state of purity.*

Purpuric acid thus obtained is a cream-coloured powder, which, when examined with a magnifier, especially in water, appears to possess a pearly lustre. It has no smell nor taste. Its specific gravity is considerably above that of water, though from its minute state of division it usually takes a considerable time to subside in that fluid.

It is very little soluble in water; 10000 parts of that liquid not being capable of dissolving one part of the acid. In alcohol and ether it is quite insoluble. It dissolves readily in the concentrated mineral acids, and in the alkaline solutions; but it is insoluble, or nearly so, in dilute sulphuric, muriatic, and phosphoric acids, and also in solutions of oxalic, tartaric, and citric acids. Concentrated nitric acid dissolves it readily with effervescence and purpurate of ammonia is obtained. Chlorine likewise dissolves it, and produces a similar change on it. It dissolves also when assisted by heat in concentrated acetic acid.

It does not sensibly alter the colour of litmus paper. When exposed to the air it does not deliquesce. But it becomes gradually red, and some purpurate of ammonia seems to be formed in it.

When heated it neither melts nor sublimes, but acquires a purple hue from the formation of ammonia, and afterwards burns gradually without yielding any remarkable odour. When distilled it yields a good deal of carbonate of ammonia, some prussic acid, and a little fluid having an oily appearance, while a pulverulent charcoal remains.

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* Phil. Trans. 1818, p. 420.

It combines with bases, and forms salts to which the name of *purpurates* has been given. The greater number of these purpurates have a red colour, though some of them are green and some of them yellow. Purpuric acid is capable of decomposing the carbonates when assisted by heat, and it does not, as far is known, combine with any other acid.

Dr. Prout made some trials to determine the composition of this acid by heating it with peroxide of copper. The result of his experiments gave the constituents as follows:

2 atoms hydrogen . . . . . . = 0·25
2 atoms carbon . . . . = 1·50
1 atom azote . . . . = 1·75
2 atoms oxygen . . . . = 2·00
5·50

According to this analysis the equivalent number for purpuric acid is 5·5 or a multiple of it.*

SECT. XX.

OF LACCIC ACID.

THIS is an acid lately obtained by Dr. John from *stick lac*.† His process was the following. Stick lac was reduced to powder, and digested in water as long as it communicated any colour. The aqueous solution was evaporated to dryness, and the residue digested in alcohol. The alcoholic solution was likewise evaporated to dryness, and the dry residue digested in ether. The ether solution being also evaporated left a syrupy mass of a light yellow colour, which being again dissolved in alcohol, and the solution mixed with water, lets fall a little resin. The liquid now contains the *laccic acid*, united with a little potash and lime from which it may be separated by precipitating it with lead, and decomposing the laccate by means of a quantity of sulphuric acid, just sufficient to saturate the oxide of lead. Thus obtained, it possesses the following properties.

Preparation.

1. It is capable of crystallizing. Its colour is wine yellow. Its taste is acid. It is soluble in water, alcohol, and ether.

Properties.

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* Prout, Phil. Trans. 1818, p. 420.

† Lac is a substance formed by insects in India. It will be described hereafter when treating of *resins*.

2. It throws down lead and mercury from their solutions in acids white. But it does not precipitate lime water, nor the nitrates of silver and barytes.

3. Whether pure, or combined with a base, it throws down the salts of iron white.

4. Its compounds with lime, soda, and potash, are deliquescent and soluble in alcohol.*

SECT. XXI.

OF MALIC ACID.

Preparation.

This acid, which was discovered by Scheele in 1785, has received the name of *malic acid*, because it may be obtained in abundance from the juice of apples, in which it exists ready formed. Scheele has given us the following process for extracting it: saturate the juice of apples with potash, and add to the solution acetate of lead till no more precipitation ensues. Wash the precipitate carefully with a sufficient quantity of water; then pour upon it diluted sulphuric acid till the mixture has a perfectly acid taste, without any of that sweetness which is perceptible as long as any lead remains dissolved in it; then separate the sulphate of lead, which has precipitated, by filtration, and there remains behind malic acid.†

M. Braconnot has shown that when malic acid is obtained by this process of Scheele, it is contaminated with a mucilaginous matter, intermediate between sugar and gum, which masks all its properties.‡

Vauquelin ascertained that it may be extracted, with greater advantage, from the juice of the *sempervivum tectorum*, or common house-leek, where it exists abundantly, combined with lime. The process which he found to answer best is the following: to the juice of the house-leek add acetate of lead as long as any precipitate takes place. Wash the precipitate, and decompose it by means of diluted sulphuric acid in the manner directed by Scheele.§

Gay-Lussac has shown that when malic acid is obtained in this way, it still retains a quantity of lime, from which it may

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* Schweigger's Journal, xv. 110.

† Swedish Trans. and Crell's Annals for 1785.

‡ Ann. de Chim. et de Phys. viii. 149.

§ Ann. de Chim. xxxiv. 127.

be freed by evaporating it to the consistence of a syrup, and mixing it with alcohol. Malate of lime is precipitated, and the malic acid remains dissolved in the alcohol.* But the acid even when thus purified, retains the mucilaginous matter with which it is contaminated when extracted from the juice of apples, as Braconnot has shown.†

In the year 1815, Mr. Donovan announced the existence of a new acid in the expressed juice of the berries of the *pyrus aucuparia*, to which he gave the name of *sorbic acid*. His method of procuring this acid was the following:

Preparation.

The berries are to be collected when fully ripe. They are to be first bruised in a mortar, and then squeezed in a linen bag. They yield nearly half their weight of juice of the specific gravity 1·077. This juice is to be strained and mixed with a filtered solution of acetate of lead. Separate the precipitate on a filter, and wash it with cold water. A large quantity of boiling water is then to be poured upon the filter, and allowed to pass through the precipitate into glass jars. After some hours this liquid becomes opake, and deposites crystals of great lustre and beauty. The matter remaining on the filter has now become hard and brittle. But it may be made to furnish more crystals by the following treatment. Boil it for half an hour with rather more diluted sulphuric acid than is sufficient to saturate the whole lead which it contains. Filter the liquid and treat it again with acetate of lead. The edulcorated precipitate, when treated as before with boiling water, yields an additional crop of crystals. This process may be repeated till almost the whole acid has been obtained united to lead in a crystallized state.

Collect the crystals formed, and boil them for half an hour with 2·3 times their weight of sulphuric acid of the specific gravity 1·090, supplying water as fast as it evaporates, and taking care to keep the mixture constantly stirred with a glass rod. The clear liquor is to be poured off and put into a tall glass jar of small diameter. While still hot, a stream of sulphuretted hydrogen gas is to be passed through it. When the lead is all precipitated the fluid is to be filtered and boiled in an open bason till the sulphuretted hydrogen is disengaged. The liquid now consists of water, holding sorbic acid in solution.‡

M. Braconnot has given us the following process, for ex-

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* Ann. de Chim. et de Phys. vi. 331.

† Ibid. vol. viii. p. 149.

‡ Phil. Trans. 1815

tracting this acid from the berries of the pyrus aucuparia, which he recommends as easier than the process of Donovan.

The berries are to be taken before they are ripe, pounded in a marble mortar, and the juice squeezed out by a strong pressure. The juice is to be heated in a capsule, to the boiling temperature, and carbonate of lime is to be thrown in as long as any effervescence continues. Evaporate the liquid to the consistence of a syrup, taking care to skim off the scum in proportion as it collects on the surface. A granular precipitate of sorbate of lime falls, which adheres strongly to the vessel, unless care be taken to stir the liquid from time to time. After an interval of some hours, decant off the syrupy liquid, and wash the precipitate with a little cold water. Then squeeze it in a cloth and dry it. The colour of this salt is fawn, indicating that it is not free from the colouring matter of the berries. Boil it for a quarter of an hour with a quantity of crystallized carbonate of soda equal to it in weight, and a sufficient quantity of water. A double decomposition takes place, and the liquid retains in solution sorbate of soda, mixed with a quantity of colouring matter. This colouring matter is removed by heating the liquid for some time with lime water, or milk of lime. The liquid when filtered becomes quite colourless. A current of carbonic acid gas passed through it precipitates the lime retained in solution. The liquid thus freed from colouring matter is to be precipitated by subacetate of lead, and the sorbate of lead may be decomposed, and the acid obtained in solution in water by digesting it with the requisite quantity of dilute sulphuric acid.[*] I have repeated this process of Braconnot very exactly; but did not succeed in freeing the acid from the colouring matter. The berries which I employed were fully ripe, while Braconnot's probably were green. Perhaps this may account for the difference between our results.

In the year 1818, Braconnot made a set of experiments on malic acid from the juice of the apple, and from the leaves of the *sempervivum tectorum*, or *houseleek*, and demonstrated that when freed from the mucilaginous matter with which it is usually mixed and disguised, it possesses exactly the properties of sorbic acid.[†] Hence it follows that sorbic acid is not a peculiar acid, as Donovan supposed; but merely the malic acid of Scheele, in a state of greater purity than that chemist had

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[*] Ann. de Chim. et de Phys. vi. 211.

[†] Ibid. vol. viii. p. 149.

been able to obtain it. Of course we must drop one or other of these two terms, and as Scheele was undoubtedly the first discoverer of this acid, though he did not succeed in procuring it in a state of purity, it seems but fair to retain the name *malic acid*, which that illustrious chemist originally bestowed on it.

Braconnot obtained pure malic acid from the juice of the house-leek, in the following manner. The expressed juice of the plant was evaporated to the consistence of a syrup, and alcohol being gradually mixed with it, threw down the precipitate usually considered as malate of lime. This precipitate was pressed strongly in a cloth to free it as completely as possible of the saccharine matter with which it was mixed. It was then dissolved in water to which it communicated a brown colour. Sulphuric acid was added to the liquid in such quantity as only partially to decompose the salt, and the liquid was filtered in order to separate the sulphate of lime precipitated. The liquid, which had now a decidedly sour taste, being set aside for 24 hours, deposited a colourless salt, consisting of bimalate of lime. This salt being redissolved and crystallized slowly, formed six sided flat prisms, terminated by bihedral summits, of the purest white colour. These crystals being dissolved in water were decomposed by sulphuric acid, and in order to get rid of all the sulphuric acid, the filtered liquid was digested over oxide of lead, and the whole being filtered, a current of sulphuretted hydrogen gas was passed through it to throw down the dissolved lead. It was now evaporated to the consistence of a syrup, and dissolved in alcohol to get rid of some lime and oxide of lead, not separated by the previous processes. The alcoholic solution being evaporated to the consistence of a syrup did not crystallize in 24 hours; but being put into a stove it crystallized completely within the same interval of time. The crystals first formed were groups of small flattened globules of about a line in diameter, and by degrees the whole concreted into an opaque white mass tuberculated on the surface.

1. Malic acid thus obtained is a white opaque substance, having an exceedingly sour taste, but destitute of smell, and exceedingly soluble both in water and alcohol.

2. When dropt into solutions of nitrate of lead, nitrate of silver, or nitrate of mercury, it occasions no precipitate. In acetate of lead it throws down a white precipitate soluble in acetic acid, and even in boiling water.

3. When acetate of lead is dropt into this acid, diluted with

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water, a copious white precipitate falls, which gradually redissolves in the liquid, and is slowly converted into very fine silky crystals, having a great deal of lustre. When these crystals are boiled in water they partially dissolve, but the greatest part of them melt into a resinous looking matter which may be drawn out into the threads, but which becomes brittle as soon as the temperature sinks.

4. Neither lime water nor barytes water occasion any precipitate when dropt into this acid.

5. The malates of potash and soda are incrystallizable, deliquescent, and insoluble in strong alcohol. But the bimalates of potash, soda, and ammonia crystallize.

6. When saturated with magnesia, or with oxide of zinc, it forms salts, which crystallize with the greatest facility.

When malic acid is heated, it sublimes, and may be collected in the form of white needles. By this treatment, its properties are somewhat altered, and it is converted into pyromalic acid.

SECT. XXII.

OF IGASURIC ACID.

THIS is the name by which Pelletier and Caventou have thought proper to distinguish an acid, which exists in St. Ignatius's bean, the fruit of the *strychnos ignatia*, in which they first detected the new alkaline substance to which they gave the name of *strychnia*. The characters which they have pointed out in the igasuric acid are scarcely sufficient to constitute it a peculiar species. I have, however, given it a provisional place here, till subsequent experiments determine whether or not it is different from malic acid, with which it has many characters in common.

Preparation.

Igasuric acid was obtained in the following manner. The magnesia by means of which the strychnia had been separated from the infusion of St. Ignatius's bean, was washed in cold water to deprive it as completely as possible of the colouring matter with which it was mixed. It was then boiled in a great quantity of distilled water to dissolve the igasurate of magnesia. The solution being concentrated by evaporation, was mixed with acetate of lead. A double decomposition took place, and the igasurate of lead was precipitated in the state of an insoluble powder. This powder was mixed with water, and the lead separated from it by means of sulphuretted hydrogen gas. The igasuric acid dissolves in the water, and may be obtained in a separate state by evaporating that liquid.

Properties.

It constitutes small hard granular crystals, which have a yellow colour, probably because not sufficiently freed from the colouring matter of the bean. Its taste is acid, and very astringent. It is very soluble both in water and alcohol. The salts which it forms with the alkalies and earths, are soluble in water and alcohol. The igasurate of barytes is very soluble, and crystallizes with difficulty in the form of mushrooms. The igasurate of ammonia does not precipitate silver, mercury, or lead. When dropt into salt of copper, the liquid becomes green, and a greenish white powder gradually precipitates, which is very little soluble in water. Igasuric acid does not alter the colour of the salts of iron.*

Such are the characters of this acid as pointed out by Pelletier and Caventou. It is distinguished from malic acid by the property of throwing down copper in the state of a greenish white powder, and by the solubility of its alkaline salts in alcohol. But in its other characters it approaches very closely to that acid.

SECT. XXIII.

OF FORMIC ACID.

History.

This acid is first mentioned in the Philosophical Transactions for 1671, in a paper by Mr. Ray, giving an account of the observations of Mr. Halse, and the experiments of Mr. Fisher, on the acid juice which is spontaneously given out by ants, and which they yield when distilled.† Mr. Fisher compares this liquor with vinegar, but points out some differences between them. Scarcely any addition was made to these facts till Margraff published a dissertation on the subject in the Berlin Memoirs for 1749, in which he describes the method of obtaining the formic acid from the *formica rufa*, or *red ant*, and points out its properties with his usual precision and method.‡ A new dissertation was published on the same subject by Messrs. Arvidson and Oehrn in 1782, in which the discoveries of Margraff were confirmed, and many new particulars

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* Jour. de Pharmacie, v. 166.

† Phil. Trans. v. 2063

‡ Margraff's Opusc. i. 291.

added. Hermbstadt's paper on the same subject appeared in Crell's Annals for 1784. His researches were directed chiefly to the purification of the formic acid. He demonstrated that the juice of ants contained several foreign bodies, and among others, that a portion of *malic acid* might be detected in it. Richter published experiments on formic acid about the year 1793, pointing out a method of procuring it in a very concentrated state.* Deyeux soon after examined it, and found it analogous to the acetic acid.† This opinion of the French chemist was confirmed in 1802, by Fourcroy and Vauquelin, who published a dissertation on ants, and concluded from their experiments, that the formic acid is nothing else than a *mixture* of the acetic and malic acids.‡ The opinion maintained by these celebrated philosophers induced Suersen to examine the subject by experiment. This chemist, in an elaborate dissertation on formic acid, published in 1805,§ shows that most of the facts pointed out by Fourcroy and Vauquelin had been already ascertained by preceding chemists; that the experiments which they detail were not sufficient to warrant their conclusions; that formic acid, when properly prepared, contains no malic acid; and that it possesses properties different from the acetic. Gehlen was induced to resume the examination of this acid, by some observations which I made upon it in a former edition of this work. He published an elaborate dissertation on it in 1812, in which he compares the properties of formic acid with those of acetic acid, and points out the peculiar characters of formic acid with great clearness and precision.||

Preparation.

The simplest method of procuring formic acid in a state of purity is that of Margraff as corrected by Richter. Suersen accordingly had recourse to it. This method is as follows: infuse any quantity of ants in about thrice their weight of water, put the mixture into a silver or tinned copper still, and draw off the water by distillation as long as it continues to come over without any burnt smell; for the distillation must be stopped as soon as that smell begins to be perceived. Saturate the water in the receiver with carbonate of potash, and evaporate to dryness. Mix the white mass thus obtained with

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* Gehlen, iv. 7.

† Fourcroy, x. 491; Eng. Trans. I have not seen either the dissertation of Richter or Deyeux.

‡ Phil. Mag. xv. 118.

§ Gehlen's Jour. iv. 1.

|| Schweigger's Journal, iv. 1.

as much sulphuric acid, previously diluted with its weight of water, as is sufficient to saturate the potash. Introduce the mixture into a retort, and distil slowly to dryness. The liquid which comes over into the receiver is to be again rectified by a very moderate heat, to get rid of any portion of sulphuric acid that may be present.

Gehlen, to be still more certain of the purity of his formic acid, saturated the acid prepared by the above process with carbonate of copper, and by the requisite evaporation, separated the formate of copper in crystals. He mixed in a retort 13 ounces of these crystals with 8 ounces 310 grains of sulphuric acid of the specific gravity 1·864 and distilled. He obtained 6 ounces 410 grains of formic acid in a state of purity. The properties of this acid are as follow:

Properties.

1. It has a sharp sour taste and cannot be crystallized, even by the application of artificial cold.

2. Its specific gravity at the temperature of 68° is 1·1168,* while that of the most concentrated acetic acid does not exceed 1·08.

Notwithstanding its greater specific gravity, it is capable of neutralizing much less of alkaline bodies than acetic acid, as appears from the following trials of Suersen. He reduced formic and acetic acids each to the specific gravity 1·0525, and ascertained how much carbonate of potash, carbonate of lime, and carbonate of magnesia, the same weight of each of these liquids was capable of neutralizing. The result may be seen in the following little table:

	Formic Acid.	Acetic Acid.
Potash	336·8	465·1
Lime	166	231
Magnesia	150	213

3. When distilled with alcohol it forms an ether which has the odour of peach blossoms, although no prussic acid can be detected in it.†

4. Gehlen has described at considerable length the properties of formate of soda and formate of copper, and shown that their properties are very different from the acetates of the same bases. The formate of copper crystallizes in six-sided prisms. They have a bluish green colour and a specific gravity of 1·815, while the specific gravity of acetate of copper is

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* Schweigger's Jour. iv. 14.

† Gehlen, ibid.

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1·914. It is more soluble in water and less soluble in alcohol than acetate of copper.

5. Berzelius has lately analysed formic acid with much precision.* According to his experiments it is composed of

Hydrogen	2·84
Carbon	32·40
Oxygen	64·76
	100·00

Formate of lead, according to his experiments, is composed of

Formic acid	100	4·696
Oxide of lead	298·1	14

According to this analysis, the equivalent number for formic acid is 4·696. Comparing this with the analysis of formic acid, we find that its constitution must be as follows:

1 atom hydrogen	= 0·125
2 atoms carbon	= 1·5
3 atoms oxygen	= 3·
	4·625

According to this estimate it differs from oxalic merely in containing 1 atom of hydrogen, which seems to be wanting in that acid.

SECT. XXIV.

OF LACTIC ACID.

History and preparation.

When milk is kept for some time it turns sour; Scheele examined the acid thus evolved, and gave it the name of *lactic acid*. He directs the following method of procuring it:

Evaporate a quantity of sour whey to an eighth part, and then filtrate it: this separates the cheesy part. Saturate the liquid with lime-water, and the phosphate of lime precipitates. Filtrate again, and dilute the liquid with three times its own bulk of water; then let fall into it oxalic acid, drop by drop, to precipitate the lime which it has dissolved from the lime-water; then add a very small quantity of lime-water, to see whether too much oxalic acid has been added. If there has,

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* Annals of Philosophy, ix. 107.

oxalate of lime immediately precipitates. Evaporate the solution to the consistence of honey, pour in a sufficient quantity of alcohol, and filtrate again; the acid passes through dissolved in the alcohol, but the sugar of milk and every other substance remains behind. Add to the solution a small quantity of water, and distil with a small heat; the alcohol passes over and leaves behind the lactic acid dissolved in water.*

From the properties of the acid procured by this process, Scheele concluded that it was very analogous to the acetic, but that it wanted something to bring it to that state. He even pointed out a method of procuring vinegar from milk in considerable quantity, and ascertained that it always yielded a little when distilled.†

In the year 1802, Bouillon Lagrange published a set of experiments on lactic acid, from which he drew as a conclusion that it is merely acetic acid contaminated with some saline and animal matter.‡ Thenard drew the same conclusion from his experiments in 1806.§ Both of these chemists had obtained the acid which they examined by distillation. But Scheele had expressly stated, that lactic acid when distilled was converted into acetic acid. The existence of lactic acid, therefore, was by no means disproved by their experiments. The subject was taken up by Professor Berzelius, in 1808. In the second volume of his Animal Chemistry, he examined the properties of lactic acid in detail, and fully established its peculiar nature.|| He employed the following process for procuring pure lactic acid:

Extract obtained by evaporating whey to dryness, consists of lactic acid, lactate of potash, muriate of potash, phosphate of lime, and some animal matter. It was dissolved in alcohol and mixed with alcohol, holding $\frac{1}{76}$th of its weight of concentrated sulphuric acid till there was an excess of sulphuric acid in the solution. Some sulphate of potash was precipitated. To get rid of the other acids it was digested over carbonate of lead, till the liquid acquired a sweetish taste. By this the sulphuric acid, the phosphoric acid, and most of the muriatic acid were separated; but lactic acid forming a soluble compound with lead remained in solu-

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* Scheele, Stockholm Trans. 1780.

† Scheele, ii. 66.

‡ Ann. de Chim. l 288.

§ Ann. de Chim. lix. 280.

|| Forelasningar i D'jurkemien, ii. 450. A translation of his account of lactic acid is published in the Phil. Mag. xli. 241.

tion. A current of sulphuretted hydrogen gas being passed through the liquid threw down the lead. The liquid was now digested over quicklime till all the animal matter was separated. It now contained only lactic acid, muriatic acid, and lime. A portion of it was taken and freed from its lime by means of oxalic acid. This portion was then saturated with carbonate of silver. By means of this solution the remainder of the liquid was freed from muriatic acid. Finally, the lime was thrown down by means of oxalic acid, so that nothing remained but lactic acid dissolved in water. To get rid of a small portion of oxalate of lime which it may hold in solution, it is proper to evaporate it to dryness and redissolve it in water.

Properties.

1. Lactic acid, thus obtained, has a brownish yellow colour, and a sharp sour taste which is much weakened by diluting the acid with water. While cold it has no smell, but when heated it acquires a sharp sour odour, not unlike that of sublimed oxalic acid. It does not crystallize, but when evaporated to dryness forms a smooth varnish which gradually attracts moisture from the air. It dissolves readily in alcohol. When heated it boils, emits a sour smell, and leaves a bulky charcoal not easily burnt. When distilled it gives out empyreumatic oil, water, acetic acid, carbonic acid, and inflammable gas.

2. All the salts which it forms with bases are soluble in water, and hardly any of them can be made to assume a crystallized form.

3. Lactate of potash forms a light yellow transparent gummy mass, which cannot easily be made hard. When mixed with concentrated sulphuric acid no smell of acetic acid is perceived. It dissolves readily in alcohol.

4. Lactate of soda possesses nearly the same characters.

5. Lactate of ammonia has some tendency to crystallize. It forms a gummy mass, which acquires in the air an excess of acidity. When heated, most of the ammonia is driven off, and the residual acid salt deliquesces in the air.

6. Lactate of barytes, when evaporated, leaves a gummy mass soluble in alcohol. Sublactate of barytes is a doughy matter which alcohol does not dissolve.

7. Alcohol, likewise, divides lactate of lime into two portions. It leaves a sublactate undissolved in the state of powder. It dissolves the neutral lactate and gives a shining yellow varnish which, when slowly dried, cracks all over, and becomes opake.

8. Lactate of magnesia evaporated to the consistence of a syrup, and left in a warm place, shoots into granular crystals. When hastily evaporated to dryness it forms a gummy mass, separable by alcohol into lactate and sublactate.

9. Ammoniaco-magnesian lactate formed by precipitating the preceding lactate by caustic magnesia as long as any precipitate falls, shoots into needle-form crystals, which are not altered by exposure to the air.

10. Lactate of silver is of a light greenish yellow colour and metallic taste. When slowly dried, it forms a very shining varnish.

11. Protolactate of mercury has a light yellow colour, deliquesces in the air, contains an excess of acid, and is soluble in alcohol. Perlactate of mercury is a red gummy deliquescent salt.

12. There are three lactates of lead. The lactate of lead may be obtained by disgesting a solution of lactic acid in alcohol on litharge It forms grey crystalline grains. Sublactate of lead is obtained by digesting the liquid on a greater proportion of litharge. The litharge becomes lighter coloured, swells, and withdraws the acid from the liquid. Superlactate is obtained by digesting lactic acid on carbonate of lead. It does not crystallize, but forms a syrup-like mass with a sweet austere taste.

13. Lactate of iron has a reddish brown colour. It does not crystallize, and is insoluble in alcohol.

14. Lactate of zinc crystallizes. Lactic acid dissolves both zinc and iron, disengaging hydrogen gas.

15. Lactate of copper, according to the different degrees of saturation, varies from blue to green and dark blue.

Such are the properties of this acid determined by Berzelius. They are sufficient to distinguish it from every other species of acid, and to establish its peculiar nature. According to Berzelius, sublactate of lead is composed of

Lactic acid	17	2·867
Oxide of lead	83	14

If we suppose it a compound of 2 atoms oxide of lead and 1 atom acid, the weight of an atom of this acid would be 5·734. Probably 5·75 may be nearly the true number.

When oatmeal, rice, and several other vegetable bodies are mixed with water, and left to spontaneous fermentation, they acquire an acid taste and smell. The acid thus formed was examined by Braconnot, who considered it as a new acid, and gave it the name of *nanceic acid.*[*] In the last edition of this work I changed this improper term into *zumic* acid; but stated at the same time my suspicion that this supposed new acid was merely lactic acid in a state of purity. This opinion of mine has been since confirmed by Vogel, who informs us that he has compared the two acids, and found their characters identical.[†]

It follows from this that lactic acid, when pure, is colourless. It is not impossible that it might be made to crystallize, if it were placed in the same circumstances that enabled malic acid to assume a crystallized form.

SECT. XXV.

OF KRAMERIC ACID.

The *Krameria triandra* is a plant which vegetates in Peru, the root of which is remarkable for its astringent properties, and is said to be employed, by the natives of the country where it grows, as a medicine of great efficacy in cases of atonic hæmorrages. It is said to be brought to London in great quantities for the purpose of giving the requisite colour to artificial imitations of wine. This root has recently attracted the attention of M. Peschier, apothecary at Geneva, who has detected in it a new acid, which he has distinguished by the name of *Krameric acid.* He obtained this acid in the following manner:

Preparation.

The root (particularly the bark) was boiled with water, and by this means a strong decoction was obtained, which had an astringent taste, and struck a black with sulphate of iron. To free it from the tannin, which it was presumed to contain, the decoction from an ounce of the root was mixed with a solution of 48 grains of gelatine, which occasioned a reddish brown deposite weighing 126 grains. To deprive the decoction of its colouring matter and of its gallic acid, which it still contained, 200 grains of sulphate of iron were added for every ounce of the root employed in making the decoction, and the liquid is then diluted with 7 or 8 pounds of water, and filtered. By this means it is rendered nearly colourless. It is then boiled with a sufficient quantity of chalk

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[*] Ann. de Chim. lxxxvi. 86.

[†] Annals of Philosophy, xii. 391.

to decompose all the sulphate of iron which it still retains, and to saturate the krameric acid present in it. The whole liquid is now passed through the filter and concentrated to the requisite degree. The lime is to be thrown down with carbonate of potash, and the kramerate of potash is precipitated by acetate of lead. The kramerate of lead being properly washed, is decomposed by a current of sulphuretted hydrogen gas. The liquid being filtered and evaporated to the requisite consistency, nothing remains but a solution of krameric acid in water.

Properties.

Krameric acid thus obtained has a strong acid taste, and leaves upon the tongue a peculiar styptic sensation. It cannot be made to crystallize. It has no action upon the salts of lime and magnesia, but it decomposes all the salts of barytes and strontian, forming two salts with each, a supersalt which is soluble, and a subsalt which is insoluble in water. Kramerate of barytes is not decomposed nor altered by sulphuric acid. So that krameric acid has a stronger affinity for barytes than sulphuric acid has. It throws down the salts of lead white. Kramerate of potash, soda, ammonia, lime, and barytes throw down the salt of iron yellow. It has no sensible action on the other metalline salts.

Kramerate of potash crystallizes in six-sided prisms.

Kramerate of soda forms large crystals, having the same shape, and efflorescing when exposed to the air.

Kramerate of ammonia yields feather-shaped crystals.

All these salts are insoluble in alcohol. They have little taste, and when thrown into a salt of barytes they occasion a precipitate.

Such are the properties of krameric acid, pointed out by M. Peschier. They will require to be verified, and I suspect rectified in several points before the peculiarity of this acid be fully demonstrated and its characters accurately determined.*

SECT. XXVI.

OF GALLIC ACID.

History.

There is an excrescence, known by the name of *nutgall*, which grows on some species of oaks. This substance contains a peculiar acid, called from that circumstance *gallic acid;*

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* See Jour. de Pharmacie, vi. 34.

the properties of which were first examined with attention by the commissioners of the Academy of Dijon, and the result of their experiments was published in 1777, in the third volume of their Elements of Chemistry.* In these experiments, however, they employed the infusion of galls, in which the acid is combined with tannin. It was reserved for Scheele to obtain it nearly in a state of purity.

Preparation.

1. He observed in an infusion of galls made with cold water a sediment, which proved on examination to have a crystalline form and an acid taste. By letting an infusion of galls remain a long time exposed to the air, and removing now and then the mouldy skin which formed on its surface, a large quantity of this sediment was obtained; which being edulcorated with cold water, redissolved in hot water, filtrated and evaporated very slowly, yielded an acid salt in crystals as fine as sand.†

Deyeux has proposed a much speedier method of obtaining gallic acid; ‡ but it does not succeed without a good deal of precaution. It consists in exposing pounded nutgalls in a large glass retort to a heat cautiously and slowly raised. A number of brilliant white crystalline plates are sublimed, which possess all the properties of gallic acid. Care must be taken not to apply too great a heat, and to stop the process before any oil begins to come over, otherwise the crystals will be redissolved, and the whole labour lost.

M. Braconnot has contrived another process, which appears to be both more economical, and more effectual than either of the preceeding ones. It is merely an improvement of the process of Scheele, and is as follows:

Two hundred and fifty grammes of nutgalls were infused for four days in a litre of water (nearly half a pound avoirdupois of nutgalls in a wine quart of water), taking care to agitate the mixture from time to time. The whole was then squeezed through a cloth, and the liquid passed through a filter. It was then left in an open glass decanter from July 22 to September 22, or two months. Its bulk had not sensibly diminished; but it had deposited a considerable quantity of

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* Vol. iii. p. 403.

† Stockholm Trans. 1786.—The crystals obtained by this method always contain a portion of tannin, and are of a brown colour.

‡ This method was in fact discovered by Scheele; but Deyeux repeated it, and pointed out the proper precautions. See Crell's Annals, i. 29. Eng. Trans.

crystals of gallic acid. These were separated by squeezing the liquid through a cloth. The liquid, when evaporated to the consistence of a syrup, deposited an additional quantity of crystals, which were separated in the same manner. The residual matter of the nutgalls from which the infusion had been procured, when moistened with water and left to spontaneous fermentation, yielded an additional crop of crystals when treated with hot water. So that nutgalls when properly treated may be made to yield the fifth part of their weight of gallic acid.

By these different processes M. Braconnot obtained 62 grammes of gallic acid, still coloured and mixed with an insoluble powder. It was boiled with 18 cubic inches of water, and filtered while boiling hot. The liquid on cooling deposited 40 grammes of crystals of gallic acid of a yellowish white colour. The mother water was brown, and when properly evaporated yielded 10 grammes more of crystallized gallic acid, darker coloured than the first crystals. To free these crystals entirely from colouring matter, they were mixed with eight times their weight of water, and about the fifth of their weight of ivory-black, and the mixture was kept for about a quarter of an hour at the boiling temperature. It was then filtered while hot; on cooling it concreted into a mass of perfectly white crystals of gallic acid, which were separated from the liquid by pressure in a cloth.*

2. Gallic acid thus obtained, is white like snow and quite pure. Its taste is weakly acid, and it leaves in the mouth an impression of sweetness.

Solubility.

3. It is soluble in 1½ parts of boiling water, and in 12 parts of cold water. When this solution is heated, the acid undergoes a very speedy decomposition. Alcohol dissolves one-fourth of its weight of this acid at the temperature of the atmosphere. When boiling hot, it dissolves a quantity equal to its own weight. It is soluble also in ether.

Action of heat.

4. When exposed to the action of heat, it is sublimed, but its properties are somewhat altered, as Bouillon Lagrange has shown. In like manner the acid sublimed by Deyeux's process differs in its properties from the crystallized acid of Scheele. Deyeux announced, that when the gallic acid is distilled it yields oxygen gas. When Berthollet repeated the experiment he obtained only carbonic acid. Bouillon Lagrange has shown, that besides the carbonic acid, there comes

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* Ann. de Chim. et de Phys. ix. 181.

over likewise a portion of heavy inflammable air, and that water is formed. By repeated distillations the whole acid may be decomposed and converted into these products.

Action of air.

5. Gallic acid in crystals is not altered by exposure to the air. Neither oxygen gas, the simple combustibles, nor azote, seem to have any particular action on it. Its action on the metals has not been examined. When the solution of this acid in water is exposed to the air, it gradually acquires a brown colour, and the acid is destroyed; the surface of the liquid becoming covered with mouldiness.

6. It combines with alkaline bodies, separating the carbonic acid if they were in the state of carbonates. The compounds formed have received the name of *gallates;* but hitherto have scarcely been examined. Indeed they may be said not to exist. For bases, as has been shown by Mr. Sertürner, have the property of acting on gallic acid and speedily decomposing it.*

Action on earths.

7. In alkaline solutions it occasions no deposit, but when dropped into barytes water, strontian water, or lime water, it gives them a bluish red colour, and occasions a flaky precipitate composed of the acid combined with the earths.†

Gallic acid occasions a precipitate when poured into solutions of glucina, yttria, and zirconia in acids. This property distinguishes these three bodies from all the other earths, none of which are precipitated from their solutions in acids by gallic acid.‡

On metals.

8. Upon the metallic solutions it acts with considerable energy, changing the colour, and producing precipitates in many of them. Hence it is frequently used as a reagent to detect the presence of metallic bodies; but the difficulty of freeing it sufficiently from tannin renders it scarcely safe to trust the experiments hitherto made on that point. Richter has shown, that it is not capable of taking iron from sulphuric acid, as has been hitherto supposed, unless it be assisted by the action of some other body which has an affinity for sulphuric acid. He has endeavoured to show, too, contrary to the experiments of Proust, that it strikes a black with all the oxides of iron. Berthollet employed his ingenuity to establish

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* Schweigger's Journal, iv. 410.

† It is not unlikely that these precipitates are occasioned by the presence of a little tannin, and that they would disappear if the acid were pure.

‡ If we except their solutions in carbonic acid. Alumina is precipitated from acids by infusion of nutgalls.

the same doctrines, but he by no means silenced Proust, who published experiments apparently decisive.

When it precipitates metallic oxides, gallic acid appears to act by bringing them nearer to the state of metals, and some of them, as gold, are completely reduced.

Composition.

9. This acid has been lately analysed with much precision by Berzelius,* according to whose experiments it is composed of

Hydrogen	5·00
Carbon	56·64
Oxygen	38·36
	100·00

According to this analysis the constitution of gallic acid is as follows:

3 atoms hydrogen .... = 0·375
6 atoms carbon ...... = 4·5
3 atoms oxygen ...... = 3·0

Atom of acid weighs .... 7·875

According to the analysis of Berzelius, gallate of lead is composed of

Gallic acid	100	8·047
Oxide of lead	173·97	14

According to this analysis the weight of an atom of gallic acid is 8, while, according to the analysis of the acid itself, its weight is 7·875. The difference between the two weights is 0·125, which is exactly an atom of hydrogen. If we consider the analysis of the gallate of lead as the more accurate, the acid, instead of 3, must contain 4 atoms of hydrogen.

SECT. XXVII.

OF TANNIN.†

History.

NUTGALLS contain several other ingredients besides gallic acid; but one of the most remarkable and important is the substance called *tannin*, which will occupy our attention in this section.

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* Annals of Philosophy, v. 176.

† The acid properties of tannin are fully as well marked as those of gallic acid. It would be better, therefore, perhaps, to give it the name of *tannic acid*.

The first attempt at a regular examination of the properties of nutgalls was made by Dr. Lewis, during a set of experiments undertaken to ascertain the best mode of making ink.* He detected in them a substance which precipitates *black* † with the oxides of iron, and *coagulates* with isinglass; ‡ but chemistry, in his time, had not made sufficient progress to enable him either to separate or examine this substance. Deyeux was, perhaps, the first chemist who ascertained the peculiar nature of *tannin.* He pointed it out in his analysis of nutgalls as a peculiar resinous substance, but without assigning it any name.§ Seguin soon after engaged in a set of experiments on the art of tanning leather; ‖ during which he discovered that *tannin* has the property of precipitating glue from its solutions in water, and of combining with the skins of animals. This led him to suppose it the essential constituent of the liquids employed for the purpose of tanning leather. Hence the names *tannin* and *tanning principle* given it by the French chemists; but it is to Mr. Proust that we are indebted for the first investigation of the nature and properties of tannin, and of the methods of obtaining it in a separate state.** Much curious and important information has likewise been obtained by the experiments of Sir H. Davy on the constituent parts of astringent vegetables, and on their operation in tanning.†† Fiedler,‡‡ Richter,§§ Merat Guillot,‖‖ and Bouillon Lagrange,*** have also published interesting experiments on this difficult subject.

An elaborate dissertation on tannin was published by Trommsdorf in the summer of 1804;††† in which he analysed the opinions of Proust, and examined the properties of tannin with his usual industry. Many of his conclusions had been anticipated by Davy, whose labours, however, they serve to corroborate and confirm; but the labours of Mr. Hatchett have formed a new era in the history of tannin. This sagacious philosopher, during a set of experiments on resins and bitumens, discovered a method of forming tannin artificially

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* Philosophical Commerce of the Arts, p. 377.

† Ibid. p. 346.

‡ Ibid. p. 387.

§ Ann. de Chim. xvii. 23.

‖ Ann. de Chim. xx. 38.

** Ann. de Chim. xxv. 225.—xxxv. 32;—and xlii. 89.

†† Phil. Trans. 1803, p 233; and Jour. of the Royal Instit. vol. ii.

‡‡ Jour. de Chim. i. 86.

§§ Jour. de Chim. iii. 307, and 334.

‖‖ Ann. de Chim. xli. 323.

*** Ann. de Chim. lvi. 172.

††† Gehlen's Jour. iii. 111.

from almost every animal and vegetable body, and thus furnished chemists with the means of procuring it with facility in a state of purity. His dissertations on an artificial tanning substance were read to the Royal Society in the summer of 1805. Substances. Chap. III.

These discoveries will make it proper for us to divide this subject into two parts. We are now in possession of two kinds of tannin; one kind formed in plants by the process of vegetation; another formed artificially by the methods pointed out by Mr. Hatchett; each of these appears capable of assuming different modifications, either from slight alterations in the constituents, or from the combination of small portions of foreign bodies.

I. NATURAL TANNIN.

1. Tannin exists in a great number of vegetable substances; but it may be procured most readily and in the greatest purity from *nutgalls* and *catechu*.

Preparation from nutgalls.

Nutgalls are excrescences formed on the leaves of the oak by the puncture of an insect which deposits it eggs on them. The best are known by the name of *Aleppo galls* imported in large quantities into this country for the use of the dyers, callico-printers, &c. They are hard like wood, round, often nodulated on the surface, of a bluish colour, and an excessively disagreeable taste. They are in a great measure soluble in water; what remains behind is tasteless, and possesses the properties of the fibre of wood. A very great proportion of water is necessary to carry off every thing soluble. Deyeux found that a French pound of nutgalls required 96 French pints of water, applied in 25 different portions one after the other, and allowed to macerate each a considerable time.* This, reduced to our standard, gives us about 150 English pints to a pound troy of nutgalls. But Trommsdorf exhausted the soluble part of nutgalls, by means of 40 times their weight of water, applied in three successive portions, each continuing two days on the galls, at the temperature of 65°.†

From the analyses of Deyeux and Davy, it follows, that the soluble part of nutgalls consists chiefly of five ingredients; namely, tannin, extractive, mucilage,‡ gallic acid, and gallate

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* Ann. de Chim. xvii. 18. † Gehlen's Jour. iii. 512.

‡ Extractive and mucilage are vegetable substances, which will be treated of in a subsequent part of this work.

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of lime. Davy found that 500 grains of Aleppo galls formed with water a solution, which yielded by slow evaporation 185 grains of matter. This matter he found composed of

130	tannin
31	gallic acid and extract
12	mucilage and extract
12	lime and saline matter
185[*]	

So that the tannin constitutes rather more than two-thirds of the whole.

Methods of obtaining it.

2. No fewer than six methods have been proposed to separate tannin from the infusion of nutgalls, and procure it in a state of purity; but none of them answers the purpose completely.

First, When a solution of muriate of tin is dropped into the infusion of nutgalls, a copious yellow precipitate immediately falls; which, when separated by filtration and dried, assumes the appearance of a buff-coloured light powder. According to Mr. Proust, who first examined this powder, it is a compound of oxide of tin and tannin. If it be mixed with water, and a current of sulphuretted hydrogen gas be passed through it, sulphuret of tin is formed, which remains insoluble; and the tannin, as it is separated from the oxide, dissolves in the water. This water, when freed from the sulphuret by filtration, and evaporated to dryness, leaves a brown-coloured substance, which Proust considered at first as pure tannin.[†] But as the infusion of nutgalls contains a portion of extract, which is likewise precipitated by muriate of tin, it is obvious, that by this process we do not obtain pure tannin, but a combination of tannin and extract. Neither is the whole of the tannin precipitated; a portion of it combined with the oxide remaining in solution, unless thrown down by an alkali.[‡] Davy has rendered it probable that this precipitate contains also muriatic acid.[§] From these facts it is obvious that pure tannin is not obtained by this process.

Second, When the infusion of nutgalls, somewhat concentrated by evaporation, is mixed with a saturated solution of carbonate of potash, a yellowish-white matter precipitates

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[*] Phil. Trans. 1803, 251.

[†] Ann. de Chim. xxv. 226.

[‡] Proust, Ann. de Chim. xlii. 89.

[§] Phil. Trans. 1803, p. 249.

abundantly in the form of flakes. When this precipitate is dried, it assumes the form of a whitish powder, which was first examined by Deyeux, to whom we are indebted for the process.* Proust considers this precipitate as pure *tannin;* and accordingly proposes this process as one of the easiest for procuring that substance from the infusion of nutgalls. According to him, carbonate of potash has a stronger affinity for water than tannin. Hence the reason that it occasions its precipitation.† But this conclusion is by no means consistent with the properties of the precipitate ascertained by Deyeux, and is altogether inconsistent with the properties ascertained by Davy. Its colour is white; it is nearly tasteless; it is not completely soluble in water; when heated, it yields crystals of gallic acid. Davy has shown that it consists chiefly of tannin and gallic acid combined with the carbonates of potash and lime.‡ The results obtained by Davy are confirmed likewise by the subsequent experiments of Trommsdorf.§ This method of course, does not yield pure tannin.

Third, When concentrated sulphuric or muriatic acid is dropped into a strong infusion of nutgalls, a white curdy precipitate immediately falls. This fact was first observed by Dizé.‖ According to Proust, the precipitate is a compound of tannin and the acid employed. If we wash it with cold water, dissolve it in boiling water, and saturate the acid with carbonate of potash, the tannin, according to him, separates in a state of purity. It may be washed with cold water and dried.** But, besides tannin, *extract* must be present in this precipitate; for it is well known that it is thrown down by sulphuric acid. Davy has rendered it probable that it contains also some gallic acid. By distilling it in a heat above 212°, he obtained a yellowish-coloured liquid, which gave a black colour to persulphate of iron, though it formed no precipitate with gelatine; it therefore contained gallic acid.†† Trommsdorf's experiments show us likewise that this method does not yield pure tannin.‡‡

Fourth, If lime-water be mixed with an infusion of nutgalls, a copious precipitate falls. When this precipitate is treated with diluted nitric or muriatic acid, an effervescence takes place, the liquid becomes deep-coloured; and when

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* Ann. de Chim. xvii. 19.

† Ann. de Chim. xxxv. 32.

‡ Phil. Trans. 1803, 245.

§ Gehlen's Jour. iii. 117.

‖ Ann. de Chim. xxxiv. 37.

** Ann. de Chim. xxxiv. 37.

†† Phil. Trans. 1803, 240.

‡‡ Gehlen's Jour. iii. 127.

filtrated leaves behind it a substance of a brilliant black colour, which Merat-Guillot, to whom we are indebted for this process, considers as pure tannin.* But Davy has shown that it must also contain the extractive matter, which is thrown down in combination with lime as well as the tannin.† The effervescence indicates sufficiently the presence of carbonic acid; a proof that the precipitate is even still more complicated. This method, then, is scarcely preferable to the former.

Fifth, The process of Bouillon Lagrange is as follows: Into an infusion of nutgalls drop a solution of crystallized carbonate of ammonia, as long as any precipitate continues to fall. Separate the precipitate by a filter, and wash it with cold water till the liquid comes off colourless. Then digest it repeatedly in alcohol, of the specific gravity 0·817, till the liquid ceases to redden the tincture of litmus. Dry it between folds of blotting paper.‡ But it is obvious that this method cannot be sufficient to separate the tannin from the extractive matter with which it appears to be chemically combined.

Sixth, The process practised by Trommsdorf, though not unexceptionable, appears to yield tannin in a state of greater purity than any other hitherto thought of. It is as follows: Three parts of nutgalls were reduced to powder, and digested with 40 parts of water for three days, at the temperature of 66°, the mixture being frequently stirred. The whole was now passed through a linen strainer, the liquid set apart, and the powdered nutgalls remaining on the strainer were treated as before with 40 parts of water. This digestion with fresh water was continued till four different infusions in all had been drawn off the nutgalls. The last of these was colourless, and produced no change upon the solution of iron. These infusions were mixed together, and evaporated gently down to one-fourth in a porcelain basin. The liquid being now muddy was passed through a thick linen cloth, by means of which a quantity of *extractive* was separated. The whole was then evaporated to the consistence of a jelly, and placed upon a flat porcelain dish near a stove till it became quite dry. The brown-coloured substance thus obtained was digested with thrice its weight of *pure* alcohol;§ and this digestion was re-

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* Ann. de Chim. xli. 323.

† Phil. Trans. 1803, 262.

‡ Ann. de Chim. lvi. 172.

§ Alcohol, of the specific gravity 0·796, is at present considered as *pure*, or free from water.

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Chap. III.

peated in all three times, till the last portion of alcohol was found to contain no trace of *gallic acid*. In order to make sure of removing the gallic acid, the dry residue was digested twice successively with alcohol containing ten per cent. of water. It was now considered as tannin in a considerable degree pure, but still contaminated with some extractive and mucilaginous matter. To get rid of these, the whole was dissolved in distilled water, and repeatedly evaporated to dryness, in hopes of rendering the extractive insoluble; but nothing was separated by this process. When the solution was left for some time in a warm place, a mould collected on the surface, which was removed, and ascribed to a portion of mucilage which had been present. The solution being now filtered, and evaporated to dryness, left a residue consisting of tannin in a state of considerable purity, but still contaminated with a quantity of sulphate of lime. To get rid of this salt, Mr. Trommsdorf employed the following method: The tannin was dissolved in water, and carbonate of potash dropped in as long as any precipitate fell. The liquid was separated from this precipitate by filtration, and mixed with acetate of lead. A powder fell, consisting of the oxide of lead combined with tannin. This powder was washed and dried; and being mixed with water, a current of sulphuretted hydrogen was passed through. By this means the lead was separated and remained in combination with sulphur, while the tannin dissolved in the water. The liquid being now filtered, boiled, and evaporated to dryness, left a residue, which may be considered as tannin in a state of as great purity as it can be procured from nutgalls.*

From catechu.

3. Catechu, or *terra japonica* as it is also called, is a substance obtained by decoction and evaporation from a species of mimosa which abounds in India. It has a reddish-brown colour, an astringent taste, leaving an impression of sweetness; it is not altered by exposure to the air. There are two varieties of it; one from Bombay, which has the lightest colour, and a specific gravity of 1·39; and one from Bengal, which is of the colour of chocolate; its specific gravity is 1·28.† This substance was examined by Davy, and found to consist chiefly of tannin combined with a peculiar species of extractive. If the darkest parts of the catechu be selected, and infused in cold distilled water for a short time, the infusion, when evaporated to dryness, consists of tannin combined with a very minute

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* Gehlen, iii. 113, and 124

† Davy, Ibid. 252.

quantity of extract. It may, therefore, be employed to ascertain the properties of tannin.

Properties.

4. Tannin procured from nutgalls by Trommsdorf's method, is a substance of a brown colour, brittle, and breaking with a resinous fracture. Its taste is bitter and very astringent, like that of nutgalls.

It dissolves readily in water, both hot and cold, and forms a solution of a brown colour, which, from Trommsdorf's experiments, does not seem liable to become mouldy, nor to undergo a spontaneous decomposition when exposed to the air in a moderate heat.

Insoluble in alcohol.

Pure alcohol does not dissolve tannin; but it is readily soluble in alcohol diluted with water, even though the portion of water be but small. Thus alcohol, of the specific gravity 0·818, dissolves it, though it contains, according to Lowitz's table, only $\frac{1}{10}$th of water. These important facts seem first to have been observed by Richter, and to have furnished him with his method of procuring gallic acid in a state of purity.

Action of oxygen.

5. From the experiments of Proust, Davy, and Deyeux, we learn that it is capable of combining with oxygen; but at the same time it is either decomposed altogether, or its nature completely altered. Thus nitric acid converts it into a yellowish brown matter soluble in alcohol, and similar in its properties to an extract.* Chlorine produces similar effects; and Mr. Proust has observed, that the peroxide of tin changes it also into an extract,† perhaps by communicating oxygen.

6. The action of the simple acidifiable combustibles on tannin has not been examined.

Action of metallic oxides.

7. The action of the metals upon tannin does not seem to be great; but almost all the metallic oxides have an affinity for it, and are capable of combining with it; the compound is usually nearly insoluble in water. Hence the reason why the infusion of nutgalls precipitates metallic solutions so readily. These compounds have been hitherto in a great measure overlooked by chemists. The following observations contain the facts at present known.

When the peroxide of tin or zinc is boiled in the infusion of galls, it acquires a dull yellow colour, and abstracts all the constituents from the infusion, leaving behind only pure water. The oxides thus combined with tannin, &c. are partly soluble in muriatic acid, and the solution indicates the presence of tan-

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[*] Davy, Phil. Trans. 1803, 241.

[†] Ann. de Chim. xlii. 93.

nin and gallic acid.* When peroxide of tin is allowed to act upon the cold infusion, it abstracts all its constituents in a few days; but Mr. Proust† affirms, that in that case the gallic acid is mostly destroyed, and a portion of the tannin brought to the state of extractive.

When the metallic salts are mixed with the infusion of galls, the precipitate consists of the metallic oxide combined with the tannin, the extract, and the acid of the infusion; and, according to Davy, it contains also a portion of the acid of the metallic salt.‡

Tannin does not seem to produce any change upon the solution of sulphate of iron: but when it is mixed with a solution of the persulphate of iron, a deep blue-coloured precipitate immediately appears, consisting of the tannin combined with the oxide. This precipitate, when dried, assumes a black colour. It is decomposed by acids.

When too great a proportion of persulphate of iron is poured into a solution of tannin, the sulphuric acid set at liberty by the combination of the iron and tannin, is sufficient to re-dissolve the precipitate as it appears: but the precipitate may easily be obtained by cautiously saturating this excess of acid with potash. When the experiment is performed in this manner, all the persulphate of iron which remains in the solution undecomposed is converted into sulphate. Mr. Proust supposes that this change is produced by the tannin absorbing oxygen from the iron.

Tannin combines with gelatine.

8. One of the most important properties of tannin is the insoluble compound which it forms with *glue* or *gelatine*, as this substance is termed by chemists. It is therefore employed to detect the presence of gelatine in animal fluids; and, on the other hand, solutions of gelatine are employed to detect the presence of tannin in vegetable fluids, and to ascertain its quantity. Now, although the compound of gelatine and tannin is insoluble in water, it is soluble both in the solution of tannin and gelatine when sufficiently diluted. It is necessary, therefore, that the solution of gelatine, used to detect tannin, should be as concentrated as is consistent with its perfect fluidity; for glue, when gelatinous, does not act upon tannin. It is necessary also that it should be employed quite fresh; for when in a state of putrefaction, it loses its property of preci-

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* Davy, Phil. Trans. 1803, p. 244.

† Ann de Chim. xlii. 92.

‡ Phil. Trans. 1803, p. 241.

pitating tannin.[*] Davy has ascertained, that the best proportion for use is a solution of 120 grains of isinglass[†] in 20 ounces of water. Care must be taken not to add an excess of the solution to the liquid from which the tannin is to be separated; because the compound of tannin and gelatine is redissolved by the solution of gelatine. According to the analysis of Davy, this compound, when dried in the temperature of 150°, is composed of

54 gelatine
46 tannin
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100[‡]

Action of alkalies.

9. Potash and soda combine with tannin, and form with it a compound less soluble in water than pure tannin, and which does not precipitate glue till the alkali is saturated with an acid.[§] Ammonia produces the same effects. The fixed alkalies occasion a precipitate in concentrated solutions of tannin, but ammonia throws down nothing.[||]

When potash or soda is added to the infusion of nutgalls, the liquid assumes a reddish-brown colour, and loses the property of precipitating gelatine till the alkali is saturated with an acid. When the alkalized infusion is evaporated to dryness, an olive-coloured mass remains, of a faint alkaline taste, which deliquesces in the air. Ammonia produces the same effect upon the infusion of galls; but when the mixture is exposed to the heat of boiling water, part of the ammonia flies off, a precipitate falls, consisting of most of the tannin and gallic acid, while the extract remains in solution.[**]

Of earths.

10. When barytes or lime water is poured into a solution of tannin, a precipitate falls, consisting of tannin combined with the earth, and the solution becomes nearly colourless. The precipitate dissolves with difficulty in water, and does not act upon the infusion of glue till the earth is saturated with an acid.[††]

When newly precipitated magnesia is agitated with the in-

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[*] I find that even the addition of as much alcohol as is consistent with the gelatine remaining in solution does not preserve it in a proper state for use.

[†] Isinglass is glue or gelatine nearly pure, as has been shown by Mr. Hatchett.

[‡] Phil. Trans. 1803, p. 235 and 250.

[§] Trommsdorf, Gehlen, iii. 144.

[||] Ibid.

[**] Davy, Phil. Trans. 1803, p. 241.

[††] Trommsdorf, Gehlen's Jour. iii. 145.

fusion of tannin, it unites with a portion of it, and forms a smoky brown powder insoluble in water, but soluble in acids. Alumina produces the same effect, and forms a similar compound.*

When barytes, strontian, or lime-water, is poured into the infusion of galls, an olive-coloured precipitate falls, which consists not only of the tannin, but also of the extract, and most of the gallic acid combined with the earth. When magnesia is mixed or boiled with this infusion, it combines with all its constituents; the gallate remains mostly in solution, and gives the liquid a green colour; while the tannin and the extract form with the magnesia an insoluble compound, and give it a dirty yellow colour. Alumina in small quantity produces exactly the same effect: but when used in a greater proportion, it separates all the constituents of the infusion.†

When the earthy carbonates are boiled in the infusion of galls, they separate the tannin and the extract, while they combine with the acid, and form with it a salt which remains in the liquid, and gives it a green colour.‡

Of acids.

11. Most of the acids have the property of combining with tannin, and of forming solutions more or less soluble. Acetic, phosphoric, oxalic, and malic acids, occasion no precipitate when dropped into a concentrated solution of nutgalls. Arsenic acid produces a copious precipitate, soluble in boiling water, and precipitating glue after the acid has been neutralized by an alkali. Muriatic acid likewise produces a precipitate mostly soluble in hot water. The same remark applies to sulphuric acid. But this acid alters and gradually decomposes tannin. Nitric acid produces no precipitate in the infusion of nutgalls. The mixture becomes hot, and assumes a red colour, which gradually changes to a yellow. By the action of this acid a bitter-tasted substance is formed, which possesses the properties of malic acid.§

12. When tannin is distilled, it yields an acid liquor, which blackens solutions of iron, because it contains a little tannin unaltered: there comes over also some empyreumatic oil, and a voluminous coal remains behind, amounting to $\frac{1}{38}$ of the tannin distilled.‖

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* Trommsdorf, Gehlen's Jour. iii. 145.

† Davy, Phil. Trans. 1803, p. 241.

‡ Ibid.

§ Trommsdorf, Gehlen's Jour. iii. 142.

‖ Proust, Ann. de Chim. xxxv. 35.

Book II. Division I.

Composition.

13. Tannin has been lately analysed with much precision by Berzelius.* He first formed a compound of tannin and yellow oxide of lead, or a tannate of lead. He found its composition as follows:

Tannin	100	26·923
Oxide of lead	52	14

From this it appears that the weight of an atom of tannin is no less than 26·923. We shall consider 26·875 as the weight of an atom of tannin as determined by this analysis. He afterwards determined the constituents of tannin to be the following:

Hydrogen	4·186
Carbon	51·160
Oxygen	44·654
	100·000

Now the constitution of tannin, as determined by these numbers, which comes nearest to its weight as resulting from tannate of lead, is as follows:

9 Atoms hydrogen = 1·125
18 Atoms carbon .. = 13·500
12 Atoms oxygen .. = 12·000
26·625

The difference between these two numbers is equivalent to two atoms of hydrogen. I think it most probable that the number 26·625 is nearest the truth.

The reader will perceive that the number of atoms in the preceding table, denoting the component parts of tannin are divisible by 3. If we perform this division, we obtain

3 Atoms hydrogen .. = 0·375
6 Atoms carbon .... = 4·500
4 Atoms oxygen .. = 4·000
8·875

Now in order that 8·875 may be the equivalent number for tannin, we have only to suppose that the salt analysed by Berzelius was a tritannate of lead; which was very probably the case. But if 8·875 be the equivalent number for tannin, it differs from gallic acid, merely by containing an additional atom of oxygen.

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* Annals of Philosophy, v. 182.

14. Such are the properties of the tannin of nutgalls, as far as they have been ascertained. The difficulty of procuring it in a state of purity renders some of them ambiguous, and has induced chemists to employ as a reagent the entire solution of nutgalls.

Writing Ink.

This solution is employed in considerable quantities by the dyers, and it forms the principal ingredient in *writing ink*. It is not known at what period this important liquid came into use; but the ink of the ancients was composed of very different ingredients, being analogous to the ink used by the printers at present. We are indebted to Dr. Lewis for a valuable set of experiments on the best mode of making ink.

This liquid consists of a solution of sulphate of iron in the infusion of nutgalls, and seems to owe its black colour chiefly to a combination of the tannin with the oxide of iron, or perhaps with the sulphate, and partly also to the combination of gallic acid and oxide of iron. The fullest black is produced when equal weights of green vitriol and galls are used; but the ink very soon fades. To make it permanent, the galls ought to be thrice the weight of the vitriol. No other solution of iron but the sulphate forms with nutgalls a full black. When the mixture of the infusion of nutgalls and green vitriol is diluted with much water, the black matter precipitates, and forms a sediment not again soluble. The addition of logwood increases the blackness of the ink. The following formula was ascertained by Dr. Lewis to yield the best ink:

Logwood	1 ounce
Nutgalls in powder	3
Green vitriol	1
Water	1 to 2 quarts.

Boil the logwood and nutgalls in the water, adding new liquid in proportion to the evaporation, then strain through a cloth, and add the vitriol to the water, adding at the same time from one to two ounces of gum arabic. As soon as these have dissolved, the ink is fit for use.[*] Some recommend the addition of a little cloves in powder to prevent mouldiness.

15. Mr. Proust has announced it as his opinion, that there exist various species of tannin in the vegetable kingdom, differing from each other like the oils, resins, &c. He has even enumerated several of these varieties, and pointed out their characteristics.[†]

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[*] See Lewis's Phil. Com. p. 377.

[†] Ann. de Chim. xlii. 94.

Book II. Division I.

Species of tannin.

It is by no means unlikely that this opinion is well founded, and the experiments of Mr. Hatchett serve to confirm it: but it is impossible to admit it as demonstrated till a process be discovered for obtaining tannin in a state of purity; for the differences between the varieties pointed out by Proust may be owing to the presence of foreign substances which disguise its properties. At any rate, this subject will come under our consideration more properly in the Second Part of this Work, when we enumerate the different vegetable substances that contain tannin.

II. ARTIFICIAL TANNIN.

Discovery.

The important discovery, that a substance possessing similar properties to the tannin of nutgalls may be formed artificially by a very simple process, was made by Mr. Hatchett in the course of a set of experiments on the slow carbonization of vegetable bodies, and detailed by him in two papers read to the Royal Society in 1805.

Formation.

1. To form this *artificial tannin*, we have only to digest diluted nitric acid on charcoal till the whole, or nearly the whole, is dissolved. Mr. Hatchett usually employed 100 grains of charcoal, and 500 grains of nitric acid of the specific gravity 1·40, diluted with twice its weight of water. On heating this mixture in an open matrass a considerable effervescence was produced, and much nitrous gas escaped. After two days digestion, more nitric acid was added, and the digestion was continued till the solution was complete. The solution thus obtained was transparent, and of a dark brown colour; which being evaporated to dryness, leaves a brown coloured mass. This is the artificial tannin. To free it from the last portions of nitric acid, Mr. Hatchett found the best method was to dissolve it repeatedly in water, and evaporate cautiously to dryness with a gentle heat.

By this method 100 grains of charcoal were converted into 120 grains of *artificial tannin;* but of these Mr. Hatchett supposes three grains to be moisture.

Properties.

2. Tannin thus prepared is a substance of a brown colour, has considerable lustre, and breaks with a vitreous fracture. Its taste is bitter and highly astringent. It has no smell.

It dissolves readily in cold water, forming a transparent solution of a deep brown colour. Alcohol also dissolves it.*

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* The alcohol used by Mr. Hatchett was probably weak. The action of pure alcohol has not been tried. Were it soluble in it, this would form a

Precipitates glue.

3. The solution of artificial tannin immediately precipitates glue, or isinglass, from water. The precipitates are more or less brown according to the strength of the solutions, and always insoluble both in hot and cold water. To ascertain the proportion in which these bodies unite, Mr. Hatchett dissolved 50 grains of artificial tannin in 4 oz. of water, and then precipitated by means of a solution of isinglass. Forty-six grains of the tannin were precipitated in combination with eighty-one grains of isinglass. Hence the precipitate is composed of about

36	tannin
64	isinglass
100	

The solution containing the four grains not precipitated by the isinglass being evaporated to dryness, left a light brittle substance of a pale brown colour, smelling strongly of prepared oak bark, especially when dissolved in water. The solution tasted bitter, and from its properties approached nearer to the vegetable matter called *extractive* than *tannin;* a proof that even the artificial tannin prepared from charcoal is not quite free from foreign bodies.

Action of acids.

4. When sulphuric acid is added to a solution of artificial tannin, a copious brown precipitate falls, soluble in boiling water, and capable of throwing down gelatine. Muriatic acid produces precisely the same effect. Artificial tannin dissolves readily in nitric acid, but is not altered in its properties, though that acid be repeatedly distilled off it. In this respect it differs very materially from all the species of natural tannin hitherto examined, which were found by Mr. Hatchett to be entirely decomposed by nitric acid, though with different degrees of facility.

Alkalies.

5. Artificial tannin unites readily with the alkalies, both fixed and volatile. When dissolved in ammonia, evaporated to dryness, and again dissolved in water, the new solution does not precipitate gelatine unless it be previously mixed with a small portion of muriatic acid. A proof that it still retains the ammonia in combination. When the fixed alkalies are added to a solution of artificial tannin, the colour is immediately deepened, and after some hours the solution becomes turbid.

marked distinction between natural and artificial tannin. I tried the effect of alcohol of the specific gravity 0·800, the strongest I had in my possession. It formed a pale yellow solution.

Carbonate of potash produces the same effect, and after some time a brown magma is deposited.

Earths.

6. The alkaline earths unite with artificial tannin, and form compounds little soluble in water. Hence it forms a precipitate when mixed with nitrates of lime, barytes, &c.

Oxides.

7. It precipitates likewise most of the metallic oxides from their solutions in acids. The colour of the precipitate is usually brown, inclining to chocolate.

Action of heat.

8. When artificial tannin is thrown upon a hot iron, it emits an odour similar to that of burning feathers. When exposed to a graduated heat in a retort there passes over, in the first place, a portion of water; and this is succeeded by a little nitric acid, from which it is difficult to free it completely. A little yellow liquor next makes its appearance; and upon raising the fire, ammoniacal gas is disengaged with great rapidity. This is followed by the evolution of carbonic acid gas, together with a small portion of gas, which seems to possess the properties of azote. A bulky coal remains in the retort, amounting in weight to 0·425 of the original tannin. This coal being burned, left some brown ashes, consisting chiefly of lime.

Constituents.

From this decomposition by the action of fire, it is obvious, that artificial tannin is composed of oxygen, azote, hydrogen, and carbon. The last ingredient obviously predominates; though the proportions have not hitherto been ascertained.

Such are the properties of the artificial tannin from charcoal, as far as they have been hitherto ascertained by Mr. Hatchett, to whom we are indebted for all the facts above detailed.* From the experiments of this indefatigable chemist, we learn that every kind of charcoal yields it equally, from whatever substance it has been formed, whether vegetable, animal, or mineral, provided it be in the state of charcoal. But the action of nitric acid on charcoal, though the readiest and easiest process, and that which yields the greatest quantity, is not the only one by means of which artificial tannin may be formed. Mr. Hatchett has pointed out two others, by means of which certain vegetable substances may be converted into tannin.

Second variety of artificial tannin.

9. The first of these consists in digesting nitric acid with certain substances that appear to contain an uncommon por-

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* From the subsequent experiments of Chevreul, it seems to follow that this artificial tannin is a compound of nitric acid and charcoal. See Ann. de Chim. lxxiii. 36.

tion of carbon in their composition; indigo, for instance, and many of the bodies called resins. Indigo dissolves readily in diluted nitric acid, and the solution, when gently evaporated to dryness, leaves an orange-coloured mass of an intensely bitter taste, soluble in water, and possessing the property of forming an insoluble precipitate with gelatine. Hence it resembles tannin; but it acts more feebly on the metallic salts than tannin from charcoal. A similar substance was procured from common resin by digesting it for a long time in diluted nitric acid. Most of the resins and gum resins gave a similar product; but no tannin could be procured from the gums.

Third variety.

10. The other process for procuring artificial tannin consists in dissolving resins and camphor in sulphuric acid, digesting the solution till it becomes black, and then precipitating by throwing it into cold water. A black powder falls. If this powder be digested in alcohol, a brown substance is taken up, which is soluble both in water and alcohol, forms an insoluble precipitate with gelatine, but acts only feebly on persulphate of iron. Camphor by this process yields nearly half its weight of a brown resinous-like matter, which possesses the property of forming an insoluble precipitate with gelatine; and when digested with a little nitric acid, becomes precisely similar to tannin from charcoal.

Thus there are three species of artificial tannin. 1. Tannin procured by the action of nitric acid on charcoal. 2. Tannin, by digesting nitric acid on indigo and resins. 3. Tannin, by dissolving resins or camphor in sulphuric acid.*

SECT. XXVIII.

OF ELLAGIC ACID.

By this very absurd name (the French word *galle* reversed) M. Braconnot has thought proper to distinguish a substance possessing imperfect acid properties, which he extracted from nutgalls at the same time with gallic acid. It would appear from a note of Chevreul that it had been already detected by him and several of its properties described in the article *tannin*, published in the chemical part of the Encyclopædie Me-

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* See Mr. Hatchett's papers, Phil. Trans. 1805 and 1806. From which all the facts respecting artificial tannin have been taken.

thodique, in 1815. But he had not given it a name, and does not seem to have been aware of its acid properties.*

Preparation.

Ellagic acid was obtained by Braconnot by filtering the solution of gallic acid obtained from the crystals which had formed spontaneously in the infusion of nutgalls. A powder remained upon the filter, which was ellagic acid mixed with a certain quantity of gallate of lime. To free it from this salt it was treated with a dilute solution of potash which dissolved the acid with the evolution of a considerable quantity of heat. The solution had an intense yellow colour, and gradually let fall a pretty considerable quantity of pearl-coloured powder, which was separated by the filter and decomposed by dilute muriatic acid.

Properties.

The ellagic acid thus obtained is a white powder with a slight shade of buff. It is tasteless, and is not sensibly soluble even in boiling water. It does not decompose the alkaline carbonates even when assisted by heat. But it unites with caustic soda and potash and destroys their alkaline characters. These salts are insoluble in water. But they become soluble if a little potash or soda be previously dissolved in that liquid. The solution has a very deep buff colour. The ellagate of ammonia is likewise insoluble, and does not become soluble even when an excess of ammonia is added. When this acid is agitated in lime water it separates the lime from the liquid. Nitric acid does not seem to act upon it at first, but if we continue the digestion it gradually assumes a blood-red colour.

Ellagic acid does not combine with iodine. When heated it does not melt, but burns away with a sort of scintillation, without emitting flame. When distilled it leaves charcoal and produces a yellow vapour, which condenses into transparent crystals of a fine greenish yellow colour. This sublimate is tasteless and insoluble in water, alcohol, and ether; but it dissolves readily in a solution of potash, and communicates a yellow colour. So that these crystals possess the same characters as the acid powder itself.†

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* Ann. de Chim. et de Phys. ix. 329.

† Ibid. p. 187.

SECT. XXIX.

GENERAL REMARKS.

Subdivis. I.
Chap. III.

In this chapter I have given an account of all the acids containing no other simple supporter than oxygen at present known. They amount to no fewer than 50. The acids containing a single combustible basis are 22, while the combustible acids amount to 28.

Though considerable progress has been made within these few years in the analyses of the combustible acids, the subject is of so difficult a nature that many experiments must still be made before their constitution can be considered as completely developed. From the sagacity and precision of Berzelius, who is engaged in the investigation, we have every reason to expect every thing that can be accomplished in the present state of the science. The following table exhibits a synoptical view of the constitution of those acids which have been analysed, arranged according to the simplicity of their constitution:

Acids.	Atoms of				Weight of an integrant particle of acid.
	Hydrogen.	Carbon.	Oxygen.	Azote.	
Oxalic	0	2	3		4·5
Formic	1	2	3		4·625
Mellitic	1	4	3		6·125
Succinic	2	4	3		6·25
Acetic	3	4	3		6·375
Citric	3	4	4		7·375
Tartaric	3	4	5		8·375
Gallic	3	6	3		7·875
Tannin	3	6	4		8·875
Pyromucic	3	9	6		13·125
Saclactic	5	6	8		13·125
Benzoic	6	15	3		15
Uric	2	6	3	2	11·25
Purpuric	2	2	2	1	5·5

Oxalic acid and formic acid differ from each other merely by the latter containing an atom of hydrogen which is wanting in the former.

Succinic and acetic acids likewise differ from each other merely in the proportion of hydrogen which they contain; acetic acid having an additional atom of hydrogen, but in other respects being the same in its composition as succinic acid.

Acetic, citric, and tartaric acids differ from each other, merely in the proportion of oxygen which they contain. If there existed a base composed of 3 atoms hydrogen + 4 atoms carbon, these three acids would all belong to that base, and consist of 3, 4, and 5 atoms of oxygen united respectively to it.

From these two examples it seems to follow that, when in combustible acids the hydrogen is increased, (the other constituents remaining the same) the solubility of the acid in water increases; but when the oxygen is increased the solubility of the acid diminishes.

The acids being so very numerous, some general remarks on the mode of distinguishing them from each other will be of considerable utility.

Suppose we possess an acid, and that we wish to determine its name.

Method of distinguishing the acids.

1. Saturate a little of it with ammonia, and form a neutral solution. Let a drop or two of this solution fall into nitrate of lead. If no precipitate fall, the acid under examination must be one or other of the following:

1. Nitric.	4. Acetic.
2. Nitrous.	5. Formic.
3. Hypophosphorous.	6. Lactic.

2. Evaporate a little of the solution of the ammoniacal salt, formed with the acid under examination to dryness, and put a little of it into a few drops of sulphuric acid placed on a slip of glass. If it be nitric, nitrous, acetic, or formic, it will emit a smell, and by the odour you can easily determine which of these acids is present.

3. If it emit no smell, take a little of the salt and expose it to the heat of a candle upon a slip of platinum. If it take fire and give out the smell of phosphorus, it is hypophosphorous acid. If it blackens, and swells, and leaves oxide of lead, the acid is lactic.

4. If the compound of the acid and ammonia occasions a precipitate in nitrate of lead, examine the appearance of this precipitate.

5. If the precipitate be *red*, the acid is the *chromic*.

6. If it effervesces when thrown into nitric acid and emits a gas *destitute of smell*, the acid is the *carbonic*.

7. If it fuses readily before the blowpipe and crystallizes on cooling into dodecahedrons, the acid is the *phosphoric.*

8. If it flies off in a white smoke before the blowpipe, having the smell of garlic, the acid is the *arsenic* or *arsenious.*

9. If the precipitate formed in nitrate of lead be soluble on adding a considerable quantity of water and agitating, the acid is the *benzoic.*

10. If the acid under examination be a dry powder insoluble in water, it is one or other of the following:

Antimonic.
Antimonious.
Molybdic.
Molybdous.
Tungstic.
Columbic.

11. If it evaporates in a white smoke before the blow-pipe, it is *antimonic* or *antimonious.* Which of the two is easily determined by the colour.

12. If the precipitate in nitrate of lead be yellow, and if the powder when dissolved in an acid and a rod of tin is put into the solution become blue, the acid is *molybdic.*

13. If the acid be a yellow powder and if when melted before the blowpipe with borax it forms a *blue* glass, but with phosphate of soda gives a green glass, it is the *tungstic.*

14. If it be in scales, little soluble in water, and when heated to redness fusing into a colourless glass, it is *boracic.*

15. *Sulphuric acid* is easily distinguished by the property which it has of forming with muriate or nitrate of barytes a white precipitate insoluble in nitric acid.

16. *Sulphurous acid* is easily distinguished by its smell.

17. *Succinic, moroxylic, boletic, suberic, and pyrotartaric* acids may be volatilized without decomposition; and they may be easily distinguished from each other by the characters assigned to each in the preceding sections.

18. *Oxalic acid* is well characterized by its crystalline form. When saturated with ammonia it throws down lime immediately from neutral nitrate or muriate of lime, which neither tartrate nor citrate of ammonia is capable of doing.

19. *Tartaric acid* is easily recognised by the property which it has of occasioning a precipitate of cream of tartar, when dropped into sulphate or nitrate of potash.

20. *Gallic* acid and *tannin* throw down sulphate of iron of a very dark blue or black colour. With the other salts of iron they strike a purple.

21. *Malic acid* forms a soluble salt with lime which is thrown down from water by alcohol.

22. *Citric acid* crystallizes. It does not throw down mercury, lead, or silver from nitric acid.

23. *Saclactic* acid is almost insoluble in water. It forms an insoluble salt with lime.

24. *Uric acid* when dissolved in nitric acid and evaporated to dryness leaves a *pink* sediment.

25. For the characters of the newly discovered acids, I refer to the sections in which they are described.

SUBDIVISION II.

OF COMPOUNDS OF CHLORINE WITH SUPPORTERS AND COMBUSTIBLES.

This subdivision may hereafter extend as far as the preceding. But as only a few years have elapsed since chlorine began to be viewed as a supporter of combustion, our knowledge of the compounds which it forms is still very imperfect. It will be sufficient, therefore, at present, if we divide this part of our subject into three chapters. In the first chapter I shall treat of the compounds which chlorine forms with oxygen, in the second of the *chlorides,* and in the third of the acids formed by the union of chlorine with the simple combustibles.

CHAP. I.

OF THE COMPOUNDS OF CHLORINE AND OXYGEN.

We have seen in a former part of this work that chlorine combines with no fewer than four proportions of oxygen, forming two oxides and two acids.* The description which we then gave of the oxides contains all the facts concerning them with which we are at present acquainted. But it would have been improper to have entered into the requisite details respecting the acids of chlorine in that early part of the work, because we were then unacquainted with the different bases

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* See vol. i. p. 193.

with which these acids unite. In this chapter, then, we have to give an account of the acids formed by the union of chlorine and oxygen.

SECT. I.

OF CHLORIC ACID.

Discovery.

BERTHOLLET was the first person who suspected the existence of this acid. He obtained chlorate of potash by passing a current of chlorine through a solution of carbonate of potash in water; and, from the properties of this salt, he concluded that it contained an acid different from chlorine. Mr. Chenevix, in his paper on the *hyperoxymuriates*, published in the Philosophical Transactions for 1802, demonstrated the accuracy of Berthollet's opinion. But he was unable to obtain the chloric acid in a separate state. Gay-Lussac procured it in 1814, and determined its properties.* The salts which it forms with the different bases were afterwards examined by Vauquelin.†

Preparation.

The process for procuring this acid in a separate state is as follows: He prepared a quantity of *chlorate of barytes*, dissolved it in water, and added diluted sulphuric acid cautiously to the solution till the whole of the barytes was exactly precipitated. The sulphate of barytes being separated by the filtre, the liquid consisted of water holding pure chloric acid in solution.

Properties.

Chloric acid, thus obtained, is a colourless liquid, destitute of smell (except when very much concentrated), having a very acid taste, and capable of reddening vegetable blues without destroying them immediately; but after acting on them for some days they disappear entirely.‡ It is not decomposed by exposure to the light. By a gentle heat it may be concentrated, and then it acquires an oily consistency. When heated strongly it is partly decomposed into oxygen and chlorine, and partly distilled over without alteration. Muriatic acid, sulphurous acid, and sulphuretted hydrogen, when mixed with it, decompose it. But nitric acid occasions no alteration in it.

It does not precipitate any of the metals from their solutions in acids. It rapidly dissolves zinc, disengaging oxygen gas.

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* Ann. de Chim. lxi. 108.

† Ibid. lxv. 91, 113.

‡ Vauquelin, Ann. de Chim. lxv. 94.

But it acts slowly upon mercury. According to the experiments of Gay-Lussac it is a compound of 1 atom chlorine + 5 atoms oxygen, or by weight of

Chlorine	4·5	100
Oxygen	5	111·11

I shall now describe the different salts which it forms with the different bases, as far as they have hitherto been examined. These salts were formerly distinguished by the name of *hyperoxymuriates;* but Gay-Lussac has given them the appellation of *chlorates*, a term which we shall adopt, because we consider it as far preferable to the old unwieldy name. The reader will observe that the weight of an atom of chloric acid is 9·5, and that the composition of all the chlorates may be determined by conceiving 9·5 of the acid to unite with the weights of the salifiable bases given in the table which will be found in vol. i. p. 542 of this work.

Chlorate of ammonia,

1. *Chlorate of ammonia.* This salt was first formed and described by Mr. Chenevix.* It was afterwards more particularly investigated by Vauquelin.† It may be formed by dissolving carbonate of ammonia in chloric acid, or by mixing a solution of carbonate of ammonia with a solution of an earthy chlorate.

It crystallizes in fine needles. It is very soluble in water and alcohol. It is volatile. Its taste is exceedingly sharp. On a burning coal it fulminates with a red flame. When heated strongly it is decomposed; chlorine is evolved, mixed with azote and oxygen, and some sal ammoniac remains in the vessel. Though this salt has not been analysed there can be no doubt that it is a compound of

Chlorine	9·5
Ammonia	2·125

Of potash,

2. *Chlorate of potash.* This salt was discovered by Berthollet,‡ and has been very much investigated by chemists in general.

It is prepared by dissolving one part of carbonate of potash

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* On Hyperoxygenized Muriatic Acid. Phil. Trans. 1802.

† Ann. de Chim. lxv. 97.

‡ It was, in fact, first discovered by Dr. Higgins, who mentions it in 1786; but appears to have mistaken it for nitre. See Higgins on Acetous Acid, &c. p. 180.

in six parts of water, putting the mixture into a Woulfe's bottle, and saturating the potash with chlorine gas.* When the saturation is nearly completed, the chlorate falls down in crystals. It may be purified by solution in boiling water. As the water cools, the pure chlorate crystallizes. The crystals are to be dried between folds of blotting-paper.

Properties.

According to Haüy, the primitive form of the crystals of chlorate of potash is an obtuse rhomboidal prism; but it is usually obtained in small thin plates of a silvery whiteness. It is only by allowing an unsaturated solution of it in boiling water to cool slowly, or by exposing a solution in cold water to spontaneous evaporation, that it is obtained in large regular rhomboidal crystals.

Its taste is cooling, austere, and disagreeable, somewhat analogous to that of nitre. Its specific gravity is 1·989.† When rubbed smartly, it phosphoresces, or rather emits a number of sparks of fire.‡ It is soluble in about 16 parts of water at the temperature of 60°, and in 2½ parts of boiling water.§ It is not sensibly altered by exposure to the air. If the heat be raised to redness, it rapidly gives out more than the third of its weight of oxygen gas. It is from this salt that oxygen gas can be obtained in the state of the greatest purity. After the effervescence is over, there remains common chloride of potassium.

The most astonishing of its properties are those which it exhibits when mixed with combustibles. All combustible substances whatever are capable of decomposing it, and in general the decomposition is attended with violent detonations.

Detonates with combustibles.

When three parts of this salt and one part of sulphur are triturated in a mortar, the mixture detonates violently: the same effect is produced when the mixture is placed upon an anvil, and struck smartly with a hammer. Nay, it even sometimes detonates spontaneously without any perceptible friction, and ought not, therefore, to be kept ready mixed. Charcoal produces the same effects, though not so violent. This property induced Berthollet to propose it as a substitute for nitre in the preparation of gunpowder. The attempt was made at Essone in 1788; but no sooner had the workmen begun to

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* The bottle containing the alkali must be covered up from the light, otherwise no crystals of chlorate can be obtained, as I have more than once experienced.

† Hassenfratz, Ann. de Chim. xxviii. 12.

‡ Fourcroy, iii. 221.

§ Hoyle, Nicholson's Jour. ii. 292.

triturate the mixture of charcoal, sulphur, and chlorate, than it exploded with violence, and proved fatal to Mr. Letors and Mademoiselle Chevraud. The force of this gunpowder, when it is prepared, is greater than that of the common sort of powder; but the danger of preparing it, and even of using it after it is prepared, is so great, that it can hardly ever be substituted with advantage for common gunpowder.

Phosphorus also detonates with this salt either by trituration or percussion. The quantities of each used ought not to exceed half a grain, or at most a grain, otherwise the experiment may be attended with some danger. It detonates also when treated in the same way with almost all the metals, and likewise with cinnabar, pyrites, sugar, gums, oils, alcohol, &c. When thrown upon platinum heated to whiteness, it does not detonate, but sublimes. The surface of the platinum, however, is oxidized; for acetic acid dissolves a part of it; and when prussiate of lime is poured into the solution, the liquid becomes of a greenish-white colour.[*] When this salt is triturated in a mortar with a little cotton cloth, small repeated explosions are heard, similar to the crack of a whip, and if the cotton be dry and warm it sometimes takes fire. It always does so when, after the trituration has been continued for some time, sulphuric acid is poured upon the cotton. When nitric acid is poured upon a mixture of chlorate of potash and phosphorus, flakes of fire are emitted at intervals for a considerable time.[†]

The theory of these explosions was first pointed out by Berthollet. The oxygen of the acid combines with the combustible, and at the same time lets go a quantity of caloric; and trituration or percussion acts merely by bringing the particles which combine within the sphere of each other's attraction.

Composition.

The composition of chloric acid has been inferred from the analysis of this salt. As chlorate of potash may be formed directly by dissolving carbonate of potash in chloric acid, there seems no reason for concluding that it consists of any thing else than chloric acid and potash united together. According to the experiments of Berzelius,[‡] 100 parts of chlorate of potash, when heated to redness, yield 38·69 parts of oxygen, and leave a residuum of 60·94 parts of chloride of patassium. This chloride is composed of

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[*] Morveau, Ann. de Chim. xxv. 18.

[†] Collier, Manchester Mem. v. 229.

[‡] Ann. de Chim. lxxx. 27.

Potassium	32·07
Chlorine	28·87
	60·94

The potassium existing in the salt in the state of potash must have been combined with $\frac{1}{5}$th of its weight of oxygen, or 6·41 parts. If we subtract this from the 38·69 parts of oxygen emitted by the salt, there will remain 32·28 for the quantity of oxygen in the chloric acid; therefore, chloric acid must be composed of

Chlorine	28·87	4·5
Oxygen	32·28	5·03

Or of 1 atom chlorine + 5 atoms oxygen. And chlorate of potash must be a compound of

Chloric acid	9·5	100
Potash	6·0	63·157

Chlorate of soda.

3. *Chlorate of soda.* Mr. Chenevix must be considered as the first chemist who published a description of this salt; for the short notice of Dolfuz and Gadolin* scarcely conveys any precise information. It may be prepared by the same process as chlorate of potash; but it is difficult to obtain it pure, as it is nearly as soluble in water as muriate of soda. Mr. Chenevix procured a little of it pure by dissolving the mixtures of muriate and chlorate of soda in alcohol, and crystallizing repeatedly. But the easiest mode of preparing it is to dissolve carbonate of soda in chloric acid. It does not crystallize till it be reduced almost to a syrupy consistence. Its crystals are square plates, similar to those of chlorate of potash. Its taste is very sharp and cooling. On burning coals it melts into globules, and produces a yellow light. According to Vauquelin, 500 parts of dry carbonate of soda produce 1100 parts of crystallized chlorate of soda.

When distilled it gives out oxygen gas mixed with some chlorine, and the salt which it leaves behind has alkaline properties. It is composed of

Chlorine	9·5	100
Soda	4	42·1

Composition.

Numbers which do not differ much from the determination of Chenevix, according to whom it is composed of

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* Ann. de Chim. i. 227.

Book II. Division I.

66·2 acid
29·6 soda
4·2 water

100·0*

Of lime.

4. *Chlorate of lime.* This salt may be procured and purified in the same way as the succeeding species. It is very deliquescent, and undergoes the watery fusion when slightly heated. Alcohol dissolves it copiously. Its taste is sharp and bitter; and when it dissolves in the mouth, it produces a strong sensation of cold. Its constituents are

Chloric acid ..	9·5	100
Lime	3·625	38·16

According to the analysis of Chenevix, its constituents are

55·2 acid
28·3 lime
16·5 water

100·0†

Of barytes.

5. *Chlorate of barytes.* It is much more difficult to procure the earthy chlorates than the alkaline; the affinity between their constituents seems to be much weaker. The best method of obtaining the chlorate of barytes is to pour warm water on a quantity of the earth procured by Vauquelin's method, and to pass a current of gas through this mixture kept warm. By this method the usual mixture of muriate and chlorate is obtained. Now these two salts, when barytes is their base, possess the same degree of solubility, and resemble each other in the form of their crystals, so that they cannot be obtained separate by repeated crystallizations. Mr. Chenevix succeeded by the following ingenious method: Phosphate of silver, when boiled in solutions of the earthy muriates, has the property of decomposing them; the phosphoric acid combines with the earth, and the muriatic acid with the oxide of silver. But this salt produces no such change on the earthy chlorates. Now both the phosphate of barytes and the muriate of silver are insoluble in water. Of course, when phosphate of silver is boiled in a solution of muriate and chlorate of barytes, the whole muriate is decomposed into muriate of silver and phos-

Formation of earthy chlorates.

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* Chenevix on Hyperoxygenized Muriatic Acid. Phil. Trans. 1802.

† Chenevix, i. Ibid.

phate of barytes, which are insoluble, and the only substance which remains in solution is chlorate of barytes.

It crystallizes in square prisms terminated by an oblique face. Its taste is sharp and austere. It dissolves in about four times its weight of cold water. The solution is neither precipitated by nitrate of silver nor muriatic acid. This salt is insoluble in alcohol. When heated, it loses 39 per cent. of weight, owing to the escape of oxygen gas. The residue possesses alkaline properties.* It is composed of

Chloric acid	9·5	100
Barytes	9·75	102·63

According to the analysis of Mr. Chenevix, its constituents are

47·0 acid
42·2 barytes
10·8 water

100·0†

Chlorate of strontian.

6. *Chlorate of strontian.* This salt was prepared and purified by Mr. Chenevix by the same processes as the last species, with which indeed it agrees in most of its properties. It is deliquescent, and more soluble in alcohol than muriate of strontian. It crystallizes in needles, which melt in the mouth, and produce the sensation of cold. On burning coals it fuses rapidly, producing a beautiful purple flame. Its constituents are

Chloric acid	9·5	100
Strontian	6·5	68·42

Composition.

According to the analysis of Mr. Chenevix, its constituents are

46 acid
26 strontian
28 water

100‡

Chlorate of magnesia.

7. *Chlorate of magnesia.* This salt may be prepared in the same way as chlorate of lime, which it resembles in most of its properties. Its constituents are

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[*] Vauquelin, Ann. de Chim. lxv. 100.

[†] Chenevix on Hyperoxygenized Muriatic Acid. Phil. Trans. 1802.

[‡] Ibid.

Chloric acid	9·5	100
Magnesia	2·5	26·31

According to the analysis of Mr. Chenevix, its constituents are

60·0 acid
25·7 magnesia
14·3 water

100·0[*]

Of iron, 8. *Chlorate of iron.* As far as we know at present this salt does not exist. Chloric acid dissolves iron with great rapidity without the evolution of any gas. The iron very speedily passes to the red oxide at the expense of the chloric acid which it decomposes. When a current of chlorine gas is passed through water, having the red oxide of iron diffused through it, the oxide is dissolved; but the compound formed appears to be merely a compound of chlorine and red oxide of iron, or a chloride of the red oxide.[†]

Of zinc, 9. *Chlorate of zinc.* This salt may be obtained by dissolving carbonate of zinc in chloric acid. The carbonic acid is disengaged; but it is difficult to saturate the chloric acid with oxide of zinc. This salt has a very astringent taste: when evaporated to the consistence of a syrup it crystallizes in low octahedrons. Its solution in water does not precipitate nitrate of silver. On burning coals it fuses and produces a yellow light, but does not detonate. When mixed with sulphuric acid it assumes an orange red colour, and produces a slight effervescence; but the chloric acid is not decomposed. For when the mixture is diluted with water, it does not precipitate sulphate of silver.[‡]

Chloric acid dissolves zinc without effervescence. It would appear from the experiments of Vauquelin that the solution is a mixture of chlorate of zinc and chloride of zinc. When a current of chlorine gas is made to pass through water, having carbonate of zinc diffused through it, the same two compounds appear to be formed.[§]

Of lead. 10. *Chlorate of lead.* This salt may be formed by dissolving litharge in fine powder in chloric acid. The solution has a very sweet and astringent taste. When left to spontaneous evapora-

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[*] Chenevix on Hyperoxygenized Muriatic Acid. Phil. Trans. 1802.

[†] Vauquelin; Ann. de Chim. xcv. 121.

[‡] Ibid. 116.

[§] Ibid.

tion it deposites brilliant crystalline plates. On burning coals it fuses and gives out a white smoke, leaving some globules of metallic lead. When distilled it yields oxygen gas mixed with a little chlorine. The quantity of oxygen amounts to about one-fifth of the weight of the salt. Sulphuric acid and the alkalies throw down a white precipitate from the solution of this salt.*

When chlorine is passed through water, having litharge diffused through it, a portion of the oxide is converted into peroxide of lead, and another portion into chloride of lead. No chlorate whatever is formed.

Of copper.

11. *Chlorate of copper.* Peroxide of copper dissolves readily in chloric acid. It is not possible to neutralize the acid by this oxide. The salt does not crystallize readily. Its colour is green. On burning coals it fuses slightly, and gives out a green light. Paper dipped into the solution of this salt burns with a fine green flame, at a temperature inferior to what would be requisite to set fire to the paper itself.†

Protochlorate of mercury.

12. *Protochlorate of mercury.* Chloric acid readily dissolves protoxide of mercury. As the saturation goes on, the protochlorate precipitates in the state of yellowish grains. This protochlorate has very much the appearance of phosphate of silver. It has a mercurial taste, and dissolves very sparingly in boiling water. When heated it detonates, oxygen gas is given out, and corrosive sublimate formed.‡

Perchlorate of mercury.

13. *Perchlorate of mercury.* This salt was first obtained by Mr. Chenevix. It may be formed readily by dissolving peroxide of mercury in chloric acid. It crystallizes in needles, is pretty soluble in water, and has a strong taste like that of corrosive sublimate. It always contains an excess of acid. When heated in a glass tube it gives out a great deal of oxygen; a yellow matter remains which appears a mixture of red oxide of mercury, corrosive sublimate, and calomel. The first portion of oxygen is disengaged with rapidity; but the last portion not till the heat is considerably elevated.§

Chlorate of silver.

14. *Chlorate of silver.* This salt was discovered by Mr. Chenevix. It may be formed by boiling phosphate of silver in chlorate of alumina, or by dissolving oxide of silver in chloric acid. It is soluble in about two parts of warm water; but as the solution cools, it crystallizes in small rhomboids, opaque and dull, like nitrate of lead or barytes. It is soluble

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* Vauquelin; Ann. de Chim. xcv. 127

† Ibid. p. 133.

‡ Ibid. p. 103.

§ Ibid. p. 107.

in alcohol. Muriatic acid decomposes it, as does nitric, and even acetic acid. The silver is thrown down from its solution by the addition of chlorine.

When this salt is exposed to a moderate heat, it melts, oxygen is given out, and chloride of silver remains behind. When mixed with half its weight of sulphur, and struck slightly, it detonates with prodigious violence. The flash is white and vivid, and accompanied by a sharp and quick noise, and the silver is reduced and volatilized.*

The remaining chlorates are still unknown.

SECT. II.

OF PERCHLORIC ACID.

This acid has been hitherto examined by Count Von Stadion only. All the facts respecting it with which I am acquainted have been given in a former part of this work.† As I feel some doubts respecting the accuracy of the Count's description of the perchlorate of potash, and of course respecting the composition of this peculiar acid, it is very much to be wished that his experiments were verified by repetition.

CHAP. II.

OF CHLORIDES.

Chlorine appears capable of combining with all the simple combustibles, except carbon. These compounds (unless when they possess acid properties) are called *chlorides.* They are analogous to the oxides, and are probably as numerous as these bodies. But it is only a few years since they became known to chemists as a distinct class of bodies. On that account it is not surprising that they have not yet been all examined. I thought it better in the present state of our knowledge, to describe the different *chlorides*, while treating of their various bases. The reader therefore will find an account of them in the chapter which treats of *simple combustibles.*

But chlorine has the property likewise of combining with

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* Chenevix on the Oxygenized and Hyperoxygenized Muriatic Acids, p. 39.

† See vol. i. p. 187.

the alkaline earths, the alkalies, and probably likewise some of the metallic oxides, and of forming a set of chlorides, some of which deserve particular attention on account of the useful purposes to which they have been applied. Of these by far the most important is the *subbichloride of lime*, commonly distinguished by the name of *oxymuriate of lime* or *bleaching powder*.

Sub-bichloride of lime.

This substance is usually sold in the state of a dry powder, and is prepared by causing a current of chlorine gas to pass through slacked lime till the powder refuses to absorb any more of the gas. It is necessary to keep the lime cold during the process, which is done by surrounding the leaden vessels in which the powder is prepared with a current of cold water. If the heat is not thus withdrawn it gradually accumulates, and at a certain temperature the lime loses its oxygen, and is converted into calcium, so that instead of chloride of lime, we obtain chloride of calcium, which possesses no bleaching powers whatever. Unslacked lime may be employed instead of hydrate of lime; but in that case it is very difficult to prevent the heat from becoming high enough to decompose the lime. I have, however, succeeded in doing this upon a small scale.

The preparation of chloride of lime in the solid state, was an idea which first struck Mr. Macintosh, of Glasgow, about the year 1798, and the idea was immediately verified by Mr. Tennant and himself. A patent was taken out and a manufactory established, which was gradually brought to the state of perfection which it has now attained.

Properties.

This chloride when recently prepared is quite dry to the feel. It is white, and has a peculiar smell bearing some relation to chlorine, but not nearly so offensive. Its taste is hot and alkaline, owing to the uncombined lime which the powder always contains. When dissolved in water the taste of the solution is astringent, and very analogous to that of chlorine itself. Water dissolves it only partially, leaving behind a quantity of lime which varies according to the care with which the chloride has been prepared. But is always considerable. This solution has the property of destroying vegetable colours, and its goodness is always determined by the bleachers by trying how much of the solution of indigo in sulphuric acid of a determinate strength can be deprived of its colour by the solution of a given weight of bleaching powder. It is this property which renders it useful in bleaching. We have only to dissolve the powder in water, draw off the clear liquor, put the cloth to be bleached into it, and allow it to remain for some hours. By this simple process it is bleached.

When chloride of lime is exposed to heat it gives out oxygen gas. This gas comes from the lime. For at a high temperature chlorine has a stronger affinity for calcium than oxygen has, and accordingly drives it off. This decomposition takes place at a temperature which does not exceed 600°. By this treatment it is converted into a mixture of chloride of calcium and lime, the former of which becomes muriate of lime when the powder is mixed with water. When the chloride of lime is dissolved in water, the very same change gradually takes place, accompanied by the same evolution of oxygen gas. Hence when the liquid is left it speedily loses its bleaching powers. Even the dry chloride undergoes the same change, though more slowly. But I have frequently kept it till its bleaching powers were entirely destroyed.

Composition.

This chloride, when perfectly pure, and when the lime is saturated with chlorine, is a compound of 2 atoms of hydrated lime and 1 atom of chlorine, or

Hydrate of lime	67·86
Chlorine	32·14
	100·00

But, though I have often analysed this chloride newly prepared by the best manufacturers, I have never found it quite free from a mixture of muriate of lime, and likewise uncombined lime. In some cases the proportion of water which the powder contains is very great, amounting nearly to one-third of the whole. The greatest proportion of lime which I have met with united with the chlorine was three-fourths of the whole, and the smallest one half. The muriate of lime present when the powder is fresh is always small, but it increases in proportion to the time that the chloride is kept. The following analysis, which is the latest that I have made, will give the reader some notion of the state in which this powder occurs in commerce. I found 100 grains of bleaching powder composed as follows:

Subbichlorate of lime	36·52
Muriate of lime	18·50
Uncombined lime	28·05
Water	16·93
	100·00

When the powder is dissolved in water, one half of the lime separates from the chlorine, so that the solution contains a chloride composed of one atom of chlorine and one atom of lime.

Method of analyzing.

The method of analysis, which I have found the most accurate, is the following. I expose a given weight of the powder (1000 grains for example) to a heat of about 600° in a retort, connected with a pneumatic trough, and receive the oxygen gas driven off in graduated jars. The loss of weight sustained by the powder, minus the weight of the oxygen gas driven off, gives the weight of the water contained in the powder. Now the oxygen given out enables us to determine very exactly the quantity of chlorine contained in the powder. For the chlorine (supposing it in the state of gas) is just double the bulk of the oxygen gas evolved. If we have obtained 300 cubic inches of oxygen gas, the chlorine in the powder will amount to 600 cubic inches.

Upon the powder remaining in the retort a considerable quantity of water is poured and digested on it till all the muriate of lime is dissolved. Through the solution a current of carbonic acid gas is to be passed to precipitate all the lime held in solution. The carbonate of lime thus separated is dried and weighed. The aqueous solution of muriate of lime is now weighed, and 100 grains of it being evaporated to dryness, we deduce from the weight of saline residue the whole muriate of lime contained in the liquid. From this it is very easy to deduce the weight of muriatic acid and of lime contained in the salt. A comparison of the chlorine in the powder with the muriatic acid in the salt enables us to determine whether any part of the muriatic acid pre-existed in the powder before the application of heat and how much.

Finally, the portion of undissolved lime is weighed and analysed.

From these data we deduce with accuracy the quantity of chlorine, of lime, of muriatic acid, and of water present in the powder. Hence we readily determine the composition.

It was Mr. Dalton that first proved that in this powder the chlorine was always combined with two atoms of lime.*

I have formed chlorides of barytes, strontian, magnesia, potash, and soda, by double decomposition from chloride of lime. They possess analogous properties; but, as they have

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* Annals of Philosophy, i. 15.

not yet been applied to any useful purpose, it would scarcely be proper to enter into particulars respecting their nature.

CHAP. III.

OF ACIDS COMPOSED OF CHLORINE AND A COMBUSTIBLE.

At present we are acquainted with two acids only of this nature. The first is a compound of chlorine and hydrogen, which constitutes the well known acid called *muriatic acid.* The second is a compound of chlorine and carbonic oxide; so that it consists of *two supporters*, *chlorine*, and *oxygen*, united to the simple *combustible*, *carbon.* This acid may be denominated *chlorocarbonic acid.* I shall describe the properties of these two acids in the two following sections.

SECT. I.

OF MURIATIC ACID.

History.

This acid appears to have been known to the alchymists. I find it mentioned in the writings of Basil Valentine. But Glauber seems to have been the chemist who contrived the present mode of obtaining it, by distilling a mixture of sulphuric acid and common salt. It was distinguished by the names of *spirit of salt*, *marine acid*, and *muriatic** *acid*, doubtless because it is obtained from *common salt.* Mr. Cavendish first obtained this acid in the gaseous state, and mentioned the circumstance in his paper *on Factitious Airs*, published in 1776;† but he does not seem to have been aware of the nature of the elastic fluid which he obtained. The subject was afterwards taken up by Dr. Priestley, who ascertained the nature and properties of muriatic acid gas, and must therefore be considered as the true discoverer of it.‡ In 1774, Scheele discovered chlorine gas, and stated the composition of muriatic acid to be *chlorine* united to *phlogiston.* By phlogiston he meant *hydrogen.* Therefore, according to the opinion of Scheele, muriatic acid is a compound of chlorine and hydrogen. This opinion was neglected for many years; but was revived again in 1810 by Sir H. Davy, in consequence chiefly of the experiments of Gay-Lussac and Thenard. The nu-

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* *Muria* is used by Cicero for *brine* or *salt water.*

† Phil. Trans. vol. lvi. p. 157.

‡ Priestley on Air, ii. 276.

merous experiments of Davy, assisted by the subsequent discovery of iodine, and its striking analogy to chlorine, seem now to have established the theory of Davy. It is admitted as true by almost all the eminent chemists in Europe.*

Since the composition of muriatic acid has become known, Gay-Lussac has thought proper to give it the new name of *hydrochloric acid* in order to point out its composition. But I do not think it right to follow his example. The term *muriatic acid* has been so long in common use, that the evils which would result from changing it, seem to more than counterbalance the slender advantages that would result from the use of a name pointing out its composition. Muriatic acid gas may be obtained in a state of purity by the following process.

Preparation.

Let a small pneumatic trough be procured, hollowed out of a single block of wood, about 14 inches long, 7 broad, and 6 deep. After it has been hollowed out to the depth of an inch, leave 3 inches by way of shelf on one side, and cut out the rest to the proper depth, giving the inside of the bottom a circular form. The figure represents a section of this trough. Two inches from each end cut a slit in the shelf to the depth of an inch, and broad enough to admit the end of small glass tubes, or the points of small retorts. This trough is to be filled with mercury to the height of ¼ inch above the surface of the shelf. Small glass jars are to be procured of considerable thickness and strength, and suitable to the size of the trough. One of them being filled with mercury by plunging it into the trough, is to be placed on the shelf over one of the slits. It ought to be supported in its position; and the most convenient method of doing that is, to have a brass cylinder two inches high screwed into the edge of the trough just opposite to the border of the shelf. On the top of it are fixed two flat pieces of brass terminating each in a semicircle, moveable freely upon the brass cylinder, and forming together a brass arm terminating in a circle, the centre of which is just above the middle of the slit in the shelf, when turned so as to be parallel to the edge of the shelf. This circle is made to embrace the jar; being formed of two distinct pieces, its size may be increased or

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* Berzelius constitutes almost the only exception. That eminent chemist still adheres to the old doctrine that *chlorine* is a compound of *muriatic* acid and *oxygen*.

diminished at pleasure, and by means of a brass slider it is made to catch the jar firmly.

The apparatus being thus disposed, two or three ounces of common salt are to be put into a small retort, and an equal quantity of sulphuric acid added; the beak of the retort plunged below the surface of the mercury in the trough, and the heat of a lamp applied to the salt in its bottom. A violent effervescence takes place; and air bubbles rush in great numbers from its beak, and rise to the surface of the mercury in a visible white smoke, which has a peculiar odour. After allowing a number of them to escape, till it is supposed that the common air which previously existed in the retort has been displaced, plunge its beak into the slit in the shelf, over which the glass jar has been placed. The air bubbles soon displace the mercury and fill the jar. The gas thus obtained is called *muriatic acid gas*. It possesses the following properties.

Properties.

1. It is invisible like common air and capable like it of indefinite contraction and expansion. Its smell is peculiar, and when let into common air it becomes visible by forming a white smoke in consequence of the avidity with which it absorbs moisture. It reddens vegetable blues and has a very sour taste.

2. Its specific gravity is 1·2847, that of common air being 1. Hence 100 cubic inches of it at the temperature of 60°, and when the barometer stands at 30 inches, weigh 39·162 grains.

Does not support combustion nor life.

3. Animals are incapable of breathing it; and when plunged into jars filled with it, they die instantaneously in convulsions. Neither will any combustible burn in it. It is remarkable, however, that it has a considerable effect upon the flame of combustible bodies; for if a burning taper be plunged into it, the flame, just before it goes out, may be observed to assume a green colour, and the same tinge appears the next time the taper is lighted.*

Absorbed by water.

4. If a little water be let up into a jar filled with this gas, the whole gas disappears in an instant, the mercury ascends, fills the jar, and pushes the water to the very top. The reason of this is, that there exists a strong affinity between muriatic acid gas and water: and whenever they come in contact, they combine and form a liquid; or, which is the same thing, the water absorbs the gas. Hence the necessity of making expe-

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* Priestley, ii. 298.

riments with this gas over mercury. In the water cistern not a particle of gas would be procured. Nay, the water of the trough would rush into the retort and fill it completely. It is this affinity between muriatic acid gas and water which occasions the white smoke that appears when the gas is mixed with common air. It absorbs the vapour of water which always exists in common air. The solution of muriatic acid gas in water is usually denominated simply *muriatic acid* by chemists.

Proportion.

A cubic inch of water at the temperature of 60°, barometer 29·4°, absorbs 515 inches of muriatic acid gas, which is equivalent to 808 grains nearly. Hence water thus impregnated contains 0·548, or more than half its weight of muriatic acid, in the same state of purity as when gaseous. I caused a current of gas to pass through water till it refused to absorb any more. The specific gravity of the acid thus obtained was 1·203. If we suppose that the water in this experiment absorbed as much gas as in the last, it will follow from it, that 6 parts of water, by being saturated with this gas, expanded so as to occupy very nearly the bulk of 11 parts; but in all my trials the expansion was only to 9 parts. This would indicate a specific gravity of 1·177; yet upon actually trying water thus saturated, its specific gravity was only 1·203. Is this difference owing to the gas that escapes during the taking of the specific gravity?

During the absorption of the gas, the water becomes hot. Ice also absorbs this gas, and is at the same time liquefied. The quantity of this gas absorbed by water diminishes as the heat of the water increases, and at a boiling heat water will not absorb any of it. When water impregnated with it is heated, the gas is again expelled unaltered. Hence muriatic acid gas may be procured by heating the common muriatic acid of commerce. It was by this process that Dr. Priestley first obtained it.

Properties.

The acid thus obtained is colourless: it has a strong pungent smell similar to the gas, and when exposed to the air is constantly emitting visible white fumes. The muriatic acid of commerce is always of a pale yellow colour, owing to a small quantity of iron which it holds in solution.

As muriatic acid can only be used conveniently when dissolved in water, it is of much consequence to know how much pure acid is contained in a given quantity of liquid muriatic

Book II.
Division I.

acid of any particular density. Mr. Dalton drew up a table from his own experiments, which possessed considerable accuracy. But the following table of Dr. Ure being more complete, will be more convenient.*

Table of the Quantity of dry Muriatic Acid corresponding to successive Specific Gravities of the liquid Acid.

Specific gravity.	Acid in 100	Specific gravity.	Acid in 100.	Specific gravity.	Acid in 100.
1·1920	28·30	1·1272	18·68	1·0610	9·05
1·1900	28·02	1·1253	18·39	1·0590	8·77
1·1881	27·73	1·1233	18·11	1·0571	8·49
1·1863	27·45	1·1214	17·83	1·0552	8·21
1·1845	27·17	1·1194	17·55	1·0533	7·92
1·1827	26·88	1·1173	17·26	1·0514	7·64
1·1808	26·60	1·1155	16·98	1·0495	7·36
1·1790	26·32	1·1134	16·70	1·0477	7·07
1·1772	26·04	1·1115	16·41	1·0457	6·79
1·1753	25·75	1·1097	16·13	1·0438	6·51
1·1735	25·47	1·1077	15·85	1·0418	6·23
1·1715	25·19	1·1058	15·56	1·0399	5·94
1·1698	24·90	1·1037	15·28	1·0380	5·66
1·1679	24·62	1·1018	15·00	1·0361	5·38
1·1661	24·34	1·0999	14·72	1·0342	5·09
1·1642	24·05	1·0980	14·43	1·0324	4·81
1·1624	23·77	1·0960	14·15	1·0304	4·53
1·1605	23·49	1·0941	13·87	1·0285	4·24
1·1587	23·20	1·0922	13·58	1·0266	3·96
1·1568	22·92	1·0902	13·30	1·0247	3·68
1·1550	22·64	1·0883	13·02	1·0228	3·39
1·1531	22·36	1·0863	12·73	1·0209	3·11
1·1510	22·07	1·0844	12·45	1·0190	2·83
1·1491	21·79	1·0823	12·17	1·0171	2·55
1·1471	21·51	1·0805	11·88	1·0152	2·26
1·1452	21·22	1·0785	11·60	1·0133	1·98
1·1431	20·94	1·0765	11·32	1·0114	1·70
1·1410	20·66	1·0746	11·04	1·0095	1·41
1·1391	20·37	1·0727	10·75	1·0076	1·13
1·1371	20·09	1·0707	10·47	1·0056	0·85
1·1351	19·81	1·0688	10·19	1·0037	0·56
1·1332	19·53	1·0669	9·90	1·0019	0·28
1·1312	19·24	1·0649	9·62	1·0000	0·00
1·1293	18·96	1·0629	9·34		

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* Annals of Philosophy, x. 371.

Dr. Ure has given a very useful approximate method of determining the weight of true acid in 100 parts of acid of any specific gravity. It is this. Multiply the decimal part of the specific gravity by 148, the product gives nearly the true weight of acid. Suppose the specific gravity of the acid to be 1·192, then 0·192 × 148 = 28·416, which we see by the table, is very nearly the quantity of acid in acid of that specific gravity.

The following table drawn up by Mr. Dalton gives us the boiling point of this acid at various densities.

Sp. gravity.	Boiling point.
1·166	170
1·154	190
1·144	212
1·136	217
1·127	222
1·121	228
1·094	232
1·075	228
1·064	225
1·047	222
1·035	219
1·018	216
1·009	214

Composition.

5. When equal volumes of chlorine and hydrogen gas are mixed together, if the mixture be exposed to the direct rays of the sun or if an electric spark be made to pass through it an explosion takes place, the two gases combine without any change of bulk and are converted into muriatic acid gas. Hence muriatic acid is a compound of equal volumes of the two gases, or it is composed by weight of

Hydrogen	0·125	1
Chlorine	4·5	36

So that muriatic acid contains $\frac{1}{37}$th part of its weight of hydrogen, and $\frac{36}{37}$ths of its weight of chlorine.

II. Muriatic acid does not seem capable of uniting with any of the simple supporters of combustion.

III. Many of the simple combustibles are capable of decomposing muriatic acid and of combining with its chlorine. This is the case with the greater number of the metals. The method is to combine the metallic oxides with muriatic acid, and to expose the muriates thus formed to a strong heat. In general the oxygen of the oxides combines with the hydrogen of the muriatic acid and flies off in the state of water, while the metallic basis remains combined with the chlorine in the state of a chloride. This decomposition does not always take place. Sometimes the heat drives off the muriatic acid and leaves the oxide without undergoing decomposition.

Muriates.

IV. Muriatic acid combines with the different salifiable bases, and forms a genus of salts called *muriates.*

I shall give a description of the muriates in this place, because they cannot with propriety be placed among the salts composed of acids which contain oxygen. Gay-Lussac has given them the name of *hydrochlorates.* But this innovation, even if called for, (which I think it is not) could not with propriety be introduced till all controversy respecting the composition of the muriates is at an end.

Muriate of ammonia.

1. *Muriate of ammonia.* This salt has been in common use for several centuries. But I do not see any proof that the ancients were acquainted with it. Tournefort appears to have known the constituents of this salt in 1700. Geoffroy junior pointed them out experimentally in 1716 and 1723,* as was afterwards done more precisely by Duhamel in 1735.† For many years the whole of the sal ammoniac used in Europe was imported from Egypt; but it is now made in great abundance both in Britain and on the continent.

Properties.

Sal ammoniac is usually in the form of a hard elastic cake; but by solution in water and proper evaporation it may be obtained in crystals. The primitive form of these crystals is, according to Haüy, the octahedron; and that of its integrant particles the tetrahedon:‡ but it crystallizes most frequently in long four-sided pyramids. It often assumes the form of plumose crystals; the individual crystals of which are long hexahedral pyramids.

The specific gravity of this salt, according to the experiments of Dr. Watson, is 1·450.§ A saturated solution of it in water at 42° is of the density 1·072.

In its ordinary compact state sal ammoniac is soluble in 3·25 times its weight of cold water;‖ but the crystals, according to Gren, dissolve at the temperature of 50° in 2·727 parts

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* Mem. Par. † Ibid. ‡ Haüy's Mineralogie, ii. 380.

§ Essays, v. 67. Wallerius makes it 1·453 (Chemistry, i. 266); and Kirwan, 1.420.

‖ Wallerius' Chemistry, i. 266.

of water.* Wenzel found it soluble in 2·24 parts of water of the temperature 144·5°.† A hundred parts of alcohol of the strength 0·834 dissolve 1½ of this salt.

In its common form (which is an opaque mass) this salt is not much affected by the air, but its crystals are liable to deliquesce.

When heated, it sublimes without decomposition in the form of a white smoke, which exhales a peculiar odour.

When this salt is sublimed with gold leaf, there is found in the neck of the retort an amethyst-coloured matter, bordering on purple, soluble in water, and forming a purple solution. When filtered, there remains behind a purple powder. This salt seems from this to be capable of oxidizing gold.‡

This salt is composed of equal volumes of ammoniacal and muriatic acid gases. It is composed therefore of 1 atom acid + 1 atom gas. Hence its constituents are

Muriatic acid	4·625	68·52	100
Ammonia	2·125	31·48	45·94
		100·00	

Of potash,

2. *Muriate of potash.* As no correct distinction can be pointed out between this salt and *chloride of potassium*, I refer to the description of that chloride in vol. i. p. 331, of this work.

Of soda.

3. *Muriate of soda.* This also agrees in its properties with chloride of sodium, which is described in vol. i. p. 339, of this work.

The acid is easily extracted from this salt by means of sulphuric acid: but to obtain the alkali at a cheap rate is not so easy. The methods which have hitherto succeeded may be reduced to two.

Decomposition of

(1.) Muriate of soda is decomposed by means of some substance which has a stronger affinity for muriatic acid than soda has. The soda by this process is set at liberty, and may be obtained by evaporation and crystallization. Barytes and potash would answer this purpose completely; but unluckily these bodies cannot be obtained sufficiently pure, except at an expence which precludes their employment. There are, however, three substances, which are also capable of setting the base of common salt at liberty, and of furnishing soda, either

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* Gren's Handbuch, i. 188.

† Verwandtschaft, 309.

‡ Storr, Crell's New Discoveries, &c. Part ii. p. 41.

pure or in the state of carbonate. These are *litharge*, *lime*, and *iron*.

1. By litharge,

When about four parts of litharge and one of common salt, properly pounded and mixed, are macerated in a little water for several hours, and stirred repeatedly, the muriatic acid gradually combines with the oxide of lead, and forms a muriate, while the soda is left in solution, and may be obtained separately by filtration and evaporation. The decomposition goes on still more rapidly if the mixture be heated during the process.

The fact, that the red oxide of lead decomposes muriate of soda, which was first observed by Scheele, has given occasion to much speculation among chemists. Mr. Hassenfratz endeavoured to account for it, by supposing that the oxide is combined with carbonic acid, and that therefore it is a case of compound affinity. Mr. Curaudau has proved that carbonic acid, instead of promoting, impedes the decomposition; and that, in fact, carbonate of lead is incapable of decomposing muriate of soda. He concludes, therefore, that the phenomenon cannot be accounted for by the commonly received laws of affinity.* Vauquelin has proved more lately, that the decomposition by means of litharge is complete, provided the quantity of that oxide be greater than that of common salt; that the resulting compound is a submuriate of lead totally insoluble in water, and which is not decomposed by alkalies. Hence he ascribes the decomposition to the attraction of muriate of lead for an excess of oxide.† But this does not account completely for the decomposition, provided it be true that oxide of lead has a weaker affinity for muriatic acid than soda has. Berthollet has at last explained this apparent anomaly by proving, that when two substances are mixed with a third, for which each has an affinity, they divide it between them in proportions corresponding to the quantity of each: and if the compound formed by one of these substances with the third be insoluble, that substance combines with the whole of the third body, and takes it completely from the other; because the insoluble compound being in fact totally abstracted from the mixture, the decomposition and partition commences again as at first after every partition. Thus when the oxide of lead and muriate of soda are mixed together, the oxide and alkali divide the muriatic acid between them, so

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* Ann. de Chim. xiv. 15.

† Ibid. xxxi. 3.

that some of the common salt is decomposed, and some muriate of lead formed immediately after the mixture. But this being in the state of *submuriate*, or altogether insoluble, separates completely from the rest; in consequence of which a new partition of the muriatic acid between the oxide and the alkali takes place; and this continues, provided the quantity of litharge be sufficient, till the common salt is entirely decomposed.

2. By lime. That the alkali may be extracted from common salt by means of lime, may be considered as a fact for which likewise we are indebted to Scheele. Cahausen indeed had hinted at it in 1717; but his treatise had been forgotten.[*] Scheele ascertained that a mixture of lime and common salt, formed into a paste, and placed in a moist cellar, was covered with an efflorescence of soda in 15 days.[†] In 1782 Morveau and Carny procured a patent from the French government to establish a manufactory at Croisic for extracting soda from common salt by means of lime. Their process was exactly the same with that of Scheele, only upon a larger scale. It does not appear, however, that the manufactory was ever established. Berthollet has rendered it probable that the soda which is found abundantly on the coast of Egypt, is formed naturally by a similar process.[‡]

3. By iron. To Scheele likewise we are indebted for the discovery that common salt may be decomposed by iron. He observed that a wooden vessel placed in a cellar, and containing brine, had its iron hoops covered with an efflorescence of soda. This induced him to dip a plate of iron into a solution of common salt, and to suspend it in a cellar. After an interval of fourteen days, he found his iron incrusted with soda.[§] The same decomposition takes place also if zinc or copper be substituted for iron.[||]

(2.) The second method of extracting soda from common salt is less direct. It consists in displacing the muriatic acid by means of some other acid, which may be afterwards easily decomposed or displaced in its turn: thus the soda is left behind at last in a state of purity. The acids which have been made choice of are the sulphuric and the acetic; the boracic, phosphoric, and arsenic acids, might indeed be employed, as

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[*] See his Helmontius Extaticus.

[†] Scheele, ii. 15.

[‡] Ann. de Chim. xxxiii. 345.

[§] Scheele, ii. 14.

[||] Athenas, Ann. de Chim. xix. 92.

they decompose common salt in a high temperature. The products in that case would be borate of soda, or the phosphate, or arseniate, of the same base, according to the acid. These salts might be afterwards decomposed by means of lime, and the soda obtained separate. But these acids are a great deal too high priced to admit of their employment.

4. By sulphuric acid and its compounds.

Sulphuric acid may be either employed in a separate state, or in combination with bases, when the salts which it then forms can be procured at a sufficiently cheap rate. Alum, sulphate of lime, and sulphate of iron, have been respectively employed with advantage to decompose common salt, and obtain sulphate of soda. Alum is said to have been first employed for that purpose by Constantini, a physician of Melle, near Osnaburg, about 1750. The process, it is affirmed, does not succeed except at a low temperature.* Sulphate of lime decomposes common salt when formed with it into balls, and exposed to a strong heat.† Much discussion has taken place among the German chemists about the possibility of decomposing common salt by means of sulphate of iron. That sulphate of soda may be obtained by exposing a mixture of these two salts to a strong heat, was first announced by Vander Ballen. This was contradicted by Hahneman, but confirmed by the experiments of Tuhten,‡ Lieblein,§ and Wiegleb.‖ It succeeded completely with the French commissioners, Lelievre, Pelletier, Darcet, and Giroud, who were appointed in 1794 to examine the different processes for obtaining soda from common salt. They ascertained also that pyrites or supersulphuret of iron may be employed for the same purpose.**

After obtaining the sulphate of soda, it is necessary to expel the acid in order to procure the soda separately. This is accomplished by calcining the salt mixed with a certain portion of charcoal or of pit-coal. By this process it is converted into sulphuret of soda, and the sulphur may be abstracted by the intervention of iron or chalk. When the sulphuret of soda is nearly in fusion, small bits of iron (the parings of tin-plate answer best) are thrown in gradually in sufficient quantity to decompose the sulphuret. The fire is raised till the mixture

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* Jour. de Min. No. iii. p. 55.

† Malherbe and Athenas, Ann. de Chim. xix.

‡ Crell's Annals, 1790, ii. 406.

§ Ibid. p. 509.

‖ Ibid. 1793, i. 201.

** Ann. de Chim. xix. 58.

melts. The sulphur, having a stronger affinity for the iron, combines with it and leaves the soda, which may be separated by solution in water, filtration, and evaporation.* Carbonate of lime may be employed also for the same purpose.†

5. By acetate of lead.

Some chemists have proposed to decompose common salt by means of acetate of lead, using either the acetate of commerce, or one formed on purpose, by combining litharge with the acid liquor obtained by distilling wood. The acetate of soda formed by mixing common salt with these acetates is afterwards calcined, in order to decompose and expel the acetic acid. But these salts are too high priced to be employed with advantage to extract soda from common salt.‡

4. *Muriate of lithia.* This salt crystallizes in cubes similar to common salt. It deliquesces very rapidly when exposed to the air. The dry salt does not fuse at a red heat: though when heated to whiteness in a platinum crucible it melts. When in its natural state it melts at a very low temperature.

5. *Muriate of morphia.* This salt crystallizes in needles, usually arranged so as to constitute feather-shaped crystals. Its taste is very bitter, and it dissolves in 10½ times its weight of cold water.

6. *Muriate of strychnia.* This salt crystallizes in fine needles, which seem to be four-sided prisms. Its taste is excessively bitter. When exposed to the air it becomes slightly opaque. When heated sufficiently it is decomposed, and muriatic acid disengaged. Its constituents according to the analysis of Pelletier and Caventou are as follows:

Muriatic acid	7·0723
Strychnia	92·9277
	100·0000§

7. *Muriate of brucia.* This salt crystallizes in four-sided prisms terminated by faces slightly inclined. It is not altered by exposure to the air. It is very soluble in water. When heated sufficiently, muriatic acid is disengaged, and the salt decomposed. Its constituents are

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* Alban, Ann. de Chim. xix. 77.—The process was discovered by Malherbe. See Jour. de Min. No. iii p. 67.

† Leblanc, Ann. de Chim. xix. 61.

‡ For a detailed account of the processes of making salt followed in different countries, the reader is referred to Brownrigg's Art of making Common Salt, and to Watson's Chemical Essays, ii. 33.

§ Jour. de Pharmacie, v. 541.

Muriatic acid	5·9533
Brucia	94·0467
	100·0000[*]

8. *Muriate of picrotoxia.* Muriatic acid of the specific gravity 1·145 has little action on picrotoxia. It dissolves it however when assisted by heat, but does not become entirely saturated: 5 parts of this acid diluted with three times its weight of water dissolve about one part of picrotoxia at a strong boiling temperature. The liquor on cooling is converted into a greyish crystalline mass composed of confused crystals. When these crystals are well washed, they are almost tasteless, and feel elastic under the teeth. They dissolve in about 400 times their weight of boiling water; but are almost entirely deposited on cooling. The solubility is much increased by the presence of an excess of acid.[†]

Muriate of lime,

9. *Muriate of lime.* Though this salt in all probability exists always rather in the state of muriate of lime than of chloride of calcium, yet as the chloride when formed artificially, exactly resembles the muriate in its properties, no accurate distinction can be pointed out between them. I refer therefore to the description of chloride of calcium, in vol. i. p. 350, of this work.

Of barytes.

10. *Muriate of barytes.* This salt likewise will be found described under the name of chloride of barium in vol. i. p. 357, of this work.

11. *Muriate of strontian.* Described in vol. i. p. 362, under the name of *chloride of strontium.*

12. *Muriate of magnesia.* Described in vol. i. p. 366, under the name of chloride of magnesium.

Muriate of yttria.

13. *Muriate of yttria.* This salt has been examined by Ekeberg,[‡] Vauquelin,[§] and Klaproth.[||] It has a strong resemblance to the nitrate of yttria. Like that salt, it dries with difficulty, melts in a gentle heat, and attracts moisture very rapidly from the atmosphere. It does not crystallize, but runs into a jelly.

14. *Muriate of glucina.* This salt has only been examined by Vauquelin; and little more is known at present concerning its properties than that it resembles nitrate of glucina, but is

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[*] Pelletier and Caventou, Jour. de Pharmacie, v. 540.

[†] Boullay; Jour. de Pharmacie, v. 1.

[‡] Crell's Annals, 1799, ii. 70.

[§] Ann. de Chim. xxxvi. 157.

[||] Beitrage, iii. 69.

more easily crystallized. When dissolved in weak alcohol, it forms an agreeable sweet liquid.

Muriate of alumina.

15. *Muriate of alumina.* This salt was first described by Margraff in his dissertation on the Earth of Alum, published in the Berlin Memoirs for 1754.* Scarcely any addition has been made to the facts which he ascertained, except by Bucholz † and Wenzel.‡

It is prepared by dissolving alumina in muriatic acid. It is always in the state of a supermuriate.

Properties.

It is scarcely possible to obtain it in the form of crystals: it is usually either gelatinous, or in the state of white powder.

It is extremely soluble in water, one part of that liquid being sufficient to reduce four parts of the dry salt to the consistence of a syrup.§ When exposed to the air, it speedily deliquesces into a liquor of a glutinous consistence.

Pure alcohol, in the mean temperature of the atmosphere, dissolves half its weight of this salt; and when boiling, it takes up at least two-thirds of its weight, but deposits again a part as the solution cools.‖

When heated, it melts and loses its acid, while the alumina remains behind in a state of purity.**

Its constituents, according to the analyses hitherto made, are as follows:

Composition.

Acid	29·8 ††	52·11 ‡‡
Base	30·0	47·89
Water	40·2	
Total	100	100

Muriate of zirconia.

16. *Muriate of zirconia.* This salt was first examined by Klaproth: it was afterwards described more particularly by Vauquelin.

It is easily formed by pouring muriatic acid on newly precipitated zirconia. It is colourless; its taste is very astringent; by evaporation it furnishes small transparent crystals in needles, which lose their transparency in the air. Muriate of zirconia is very soluble in water and in alcohol; to the flame of which it does not communicate any particular colour. Heat decom-

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* Margraff's Opusc. ii. 113.

† Beitrage, iii. 109.

‡ Verwandtschaft, p. 111.

§ Bucholz, ibid. p. 115.

‖ Margraff, p. 111.

** Ibid. p. 111.

†† Bucholz, Beitrage, iii. 111.

‡‡ Theoretical composition, supposing the salt a submuriate composed of 1 atom acid + 2 atoms alumina.

poses it; and it is decomposed likewise by the saliva when taken into the mouth.

When muriate of zirconia contains a little silica, it forms cubic crystals without consistence, and resembling a jelly. These crystals, when exposed to the air, gradually lose their transparency, and diminish in volume; and there are formed in the middle of the salt white silky needle-shaped crystals.

Muriate of zirconia is decomposed by sulphuric acid; part of the sulphate precipitates, and part remains dissolved in the muriatic acid. When this acid is driven off by heat, the remainder of the sulphate is gradually deposited: if the evaporation be stopped before the mass be reduced to dryness, it forms a kind of jelly when cold. It is also decomposed by the phosphoric, citric, tartaric, oxalic, and saclactic acids, which form with zirconia insoluble compounds that precipitate in white flakes.

Action of gallic acid.

The gallic acid poured into muriate of zirconia produces a white precipitate; but a green, bordering on grey, if the zirconia contains iron; and this last precipitate becomes, when dry, of a bright black colour, and resembles China ink. The liquid preserves a greenish colour: new portions of gallic acid produce no farther precipitation; but carbonate of ammonia separates in great abundance a flaky matter of a purplish colour, not unlike that of the leys of wine. From these experiments it follows, that gallic acid has a greater affinity for zirconia than muriatic acid has; and that the gallates of zirconia and iron are soluble in muriatic acid.

Carbonate of potash decomposes muriate of zirconia, and part of the carbonic acid combines with the earth, and renders it easily soluble in acids though dried.

Carbonate of ammonia occasions a precipitate, which is mostly dissolved by adding more carbonate.

Prussiate of mercury produces an abundant precipitate, which is soluble in muriatic acid; and which consequently is not muriate of mercury.

A plate of zinc, introduced into a solution of muriate of zirconia, occasions a slight effervescence; the liquor becomes milky, and in a few days assumes the form of a white semi-transparent jelly.

Alumina decomposes muriate of zirconia with the assistance of a slight heat; the alumina dissolves, the liquor becomes milky, and assumes the form of a jelly. When the muriate contains iron, it remains in the solution, and the precipitated zirconia is quite pure. Here, then, is a method of freeing zirconia from iron.[*]

Muriate of iron.

17. *Muriate of iron.* Muriatic acid attacks iron with great rapidity; hydrogen gas is emitted in consequence of the decomposition of water, and the iron is oxidized and dissolved. This acid dissolves likewise the oxides of iron much more readily than any other, and for that reason it is sometimes employed to take out iron-marks from linen,[†] and to remove particles of rust, which often adhere with great obstinacy to glass vessels. Muriatic acid combines both with the black and red oxides of iron, and forms with each of them a peculiar salt, the properties of which have been described by Davy. Their existence had been previously pointed out by Proust. The common muriate of iron, usually obtained by dissolving iron or its oxides in muriatic acid, is a mixture of these two salts.

1. Protomuriate.

(1.) *Muriate of iron.* When iron filings are dissolved in muriatic acid, the solution, provided it be excluded from the air, is of a pale green colour, and yields, when evaporated, crystals of muriate of iron of a pale green, which are extremely soluble in water, and soluble also, according to Davy, in alcohol. The solution attracts oxygen from the air and from nitric acid. The crystals are flat rhomboidal plates, approaching to rectangles. They are transparent at first, but speedily become yellow and opaque by exposure to the air. The taste is astringent, sweetish and acrid. This salt absorbs nitrous gas even in greater quantity than sulphate of iron, and acquires, when saturated, a dark brown colour, and a much more astringent taste than muriate of iron in its usual state. When heated, the greatest part of the gas is driven off, some red oxide of iron is precipitated, and some ammonia formed, precisely as happens to a solution of sulphate of iron impregnated with nitrous gas.[‡] This salt may be formed very readily by dissolving sulphuret of iron in muriatic acid; the sulphuretted hydrogen gas evolved preventing the absorption of oxygen from the atmosphere.[§]

Properties.

2. Permuriate.

(2.) *Permuriate of iron.* This salt may be formed by dissolving the red oxide of iron in muriatic acid, by treating the muriate of iron with nitric acid, or simply by exposing it in solution to the air. The solution of this salt is of a deep brown; its odour is peculiar, and its taste, even when much diluted

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[*] Vauquelin, Ann. de Chim. xxii. 201.

[†] But as it corrodes linen, it is the most improper acid for this purpose.

[‡] Davy, p. 180.

[§] Davy, Journal of the Royal Institution, i. 308.

Properties. with water, is exceedingly astringent. When evaporated to dryness, it yields an uncrystallizable orange-coloured mass, which deliquesces in the air, and is soluble in alcohol. This salt gives a yellow tinge to animal and vegetable substances, as is the case with chlorine. When sulphuric acid is poured upon it, the odour of chlorine is perceptible. This salt does not absorb nitrous gas. When sulphuretted hydrogen gas is made to pass through it, part of the oxygen is abstracted, and the salt is converted into muriate of iron.[*]

When this salt is distilled, chlorine passes over, and the iron is reduced to the state of black oxide. This gas is also formed and exhaled during the solution of red oxide of iron in muriatic acid, at least if the solution be promoted by the application of heat.

If the heat be increased after the permuriate of iron is evaporated to dryness, the whole salt sublimes, not however in the state of permuriate, but of simple muriate, which is capable of crystallizing.

Muriate of nickel,

18. *Muriate of nickel.* Muriatic acid scarcely attacks pure nickel, especially if it has been hammered. The best solvent is nitromuriatic acid.[†] This solution, which has a green colour, yields when evaporated irregular crystals of muriate of nickel, which are decomposed by heat and by long exposure to the air, though at first they deliquesce like nitrate of nickel.[‡]

The colour of this salt is apple-green. It stains paper yellow. When heated it loses 55 per cent. of water, and is converted into a yellow anhydrous muriate, which becomes green by absorbing water when exposed to the air. When heated sufficiently in a glass retort, that portion only which is in contact with the glass is decomposed; the rest sublimes in golden yellow flowers, which gradually absorb water and become green. Muriatic acid dissolves them with difficulty.

This salt, according to Proust, is composed of about

34	oxide
11	acid
55	water
100[§]	

Of cobalt.

19. *Muriate of cobalt.* Muriatic acid acts with difficulty

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[*] Davy, Journal of the Royal Institution, p. 181.

[†] Richter, Gehlen's Jour. iii. 257.

[‡] Bergman, ii. 268.

[§] Ann. de Chim. lx. 273.

upon cobalt even when assisted by heat; but a solution may be readily obtained by adding a little nitric acid. Muriatic acid dissolves the peroxide of cobalt with an effervescence occasioned by the emission of chlorine gas. The solution, when concentrated, is of a fine green, and blue if there be no excess of acid, but it becomes red when diluted with water. This solution, when sufficiently concentrated, yields small deliquescent crystals of muriate of cobalt. These crystals are blue, but become red when they absorb moisture.

Sympathetic ink.

The solution of this salt constitutes the first and best known of all the sympathetic inks. It is diluted with water till its colour almost disappears; and then the characters written with it on paper are invisible while cold; but if the paper be gently heated they acquire a fine green colour, which disappears again when the paper cools. This may be repeated as often as we please, provided care be taken not to heat the paper too much, otherwise the characters acquire a permanent brown colour. Klaproth affirms, that this change to green only takes place when the cobalt solution is contaminated with iron: if the cobalt be pure, the characters, instead of a green, acquire a blue colour when heated.* This sympathetic ink was first made known by Waitz in 1705:† it was described a second time by Teichmeyer in 1731;‡ and a third time by Hellot in 1737.§ The cause of this singular change of colour has not hitherto been explained in a satisfactory manner. But it is easy to show that the disappearing of the colour is owing to the absorption of moisture from the atmosphere. For the green colour is permanent if the paper be confined under the receiver of an air pump along with a flat vessel filled with concentrated sulphuric acid.

When this salt is heated to redness in a retort, those parts of it only that touch the glass are decomposed, muriatic acid and chlorine are disengaged, and the glass is tinged blue. The rest of the muriate melts, and sublimes in grey coloured flowers. These flowers dissolve with great difficulty in water. At last, however, a solution of common muriate of cobalt may be obtained.||

Muriate of manganese.

20. *Muriate of manganese.* Muriatic acid readily dissolves the protoxide or carbonate of manganese. It dissolves like-

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* Klaproth's Observations on the Fossils of Cornwall, p. 64. Eng. Trans.

† See Wiegleb's Geschichte, i. 126.

‡ Commerc. Literarum, p. 91.

§ Mem. Par. 1737.

|| Proust, Ann. de Chim. lx. 269.

wise the metal with the evolution of hydrogen gas; the solution is nearly colourless. John procured it in crystals by evaporating a portion of it to dryness, and putting the dry mass in a very concentrated solution of the salt, and keeping the liquid for some days in a temperature between 77° and 88°. The crystals are long four-sided tables terminated each way by two planes. Sometimes the edges are so truncated as to convert them into six-sided tables. They are white with a slight shade of red; are transparent, and have a caustic taste, leaving a saltish impression on the tongue. They speedily deliquesce in the air. When kept in close vessels at a temperature above 77°, they become opake, and are covered by a white powder, owing to the escape of part of their water of crystallization. When heated they undergo the watery fusion, then lose their water, and at a red heat the greatest part of their acid. Both water and alcohol dissolve more than their weight of this salt. The alcoholic solution burns with a red flame. The specific gravity of the crystals is 1·560. According to Dr. John this salt is composed of

Acid	20·04
Protoxide	38·50
Water	41·46
	100·00*

From this analysis it follows that the salt examined by John is a submuriate. If we suppose it a compound of 1 atom acid, 2 atoms protoxide of manganese, and 8 atoms water, its constituents will be

Muriatic acid	20·44
Protoxide	39·78
Water	39·78
	100·00

Muriate of cerium,

21. *Muriate of cerium.* When red oxide of cerium is treated with muriatic acid, a considerable effervescence is produced, and chlorine gas escapes. The solution obtained is a yellowish red, and the shade is the lighter the longer the liquid has boiled. By concentration and cooling, small four-sided prismatic crystals are deposited of a yellowish white colour. They are soluble in alcohol, and deliquesce when exposed to

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[*] Annals of Philosophy, ii. 267.

the air. Their taste is astringent and sweet. When the permuriate of cerium, thus formed, is exposed to heat, it is completely decomposed. The water of crystallization and excess of acid pass over first, and then chlorine; the residue is a white oxide, difficultly soluble in acids. If iron be present it is volatilized in the state of muriate.

If too strong a heat has not been applied, a portion of the salt remains undecomposed. It is white, and forms a colourless solution in water, being in reality a muriate of cerium.*

22. *Muriate of uranium.* Uranium, in the metallic state, is scarcely attacked by muriatic acid;† but it dissolves the oxide, and forms with it deliquescent crystals of a yellowish green colour, having the form of four-sided tables.‡ Of uranium,

23. *Muriate of zinc.* Muriatic acid dissolves zinc rapidly, and with effervescence, owing to the emission of hydrogen gas. The solution is colourless; and, when evaporated, does not crystallize, but assumes the form of a jelly. When distilled, a little of its acid separates, and muriate of zinc remains behind in a solid mass, easily fusible. Its specific gravity is 1·577.§ It is very soluble in water; and when exposed to the air gradually attracts moisture, and assumes a gelatinous consistence. Sulphuric acid decomposes it, and the alkalies precipitate the oxide of zinc from its solution.|| Of zinc,

24. *Muriate of cadmium.* It crystallizes in small rectangular prisms, which are perfectly transparent, and very soluble in water. When this salt is heated it loses its water of crystallization, and then melts before it is heated quite to redness, and on cooling congeals into a transparent foliated crystalline mass, having a pearly lustre, approaching to the metallic; but which, when exposed to the air, loses its transparency and its lustre, and falls down in the state of a white powder. In a strong heat the fused salt sublimes in micaceous plates, possessing the usual lustre and transparency, and undergoing the very same alteration when exposed to the air. This fused salt is composed of Of cadmium.

Oxide of cadmium	70·0247
Muriatic acid	29·9753
	100·0000

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* Klaproth, Gehlen's Jour. ii. 312. Hisinger and Berzelius, ibid. Vauquelin, Ann. de Chim. liv. 54.

† Bucholz, Gehlen's Jour. iv. 36.

‡ Klaproth, Crell's Annals, i. 130. English Edition.

§ Hassenfratz, Ann. de Chim. xxviii. 13.

|| Fourcroy, v. 383.

So that 100 parts of muriatic acid are saturated by 233·6196 parts of cadmium.—Or, if we consider this substance as a chloride of cadmium, its constituents are

Cadmium	61·3877
Chlorine	38·6123
	100·0000

Of bismuth, 25. *Muriate of bismuth.* Muriatic acid has scarcely any action on bismuth while cold; but when distilled off that metal previously reduced to powder, it gradually oxidizes, and brings it to the state of a white powder. Muriate of bismuth may be readily formed by dissolving the metal in nitromuriatic acid. When the solution is evaporated, it is said to yield small prismatic crystals.

Of lead, 26. *Muriate of lead.* This salt may be formed readily by pouring muriatic acid or an alkaline muriate into a solution of nitrate of lead. The muriate precipitates in the state of a white powder. It has a sweetish taste. Its specific gravity is 1·8226.* It is soluble in 22 parts of cold water, and this solubility is increased considerably by the presence of an acid.† It is soluble in acetic acid; a property by which it may be readily distinguished from sulphate of lead. When its solution in boiling water is allowed to cool, the salt crystallizes in very small six-sided prisms of a white colour, and a brilliant appearance like satin. These crystals are not altered by exposure to the air. It is soluble in nitric acid. Its constituents are

Muriatic acid	24·83
Protoxide of lead	75·17
	100·00

Submuriate of lead. This salt may be procured either by treating muriate of lead with a pure alkali, or by decomposing common salt by means of four times its weight of litharge. In either case a white powder remains, which is the submuriate of lead. Vauquelin first pointed it out to the peculiar atten-

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Chenevix, Nicholson's Journal, iv. 223.—According to Wenzel, water though boiled on muriate of lead, takes up only $\frac{1}{30}$th of that salt. Verwandtschaft, p. 311.

tion of chemists.* It had been previously mentioned by Bergman. It is insoluble in water. When heated, it assumes a fine yellow colour. Nitric acid dissolves the excess of oxide, and leaves muriate of lead in crystals. The fixed alkalies dissolve it without decomposition. This salt is employed as a yellow paint.

Of tin,

27. *Muriate of tin.* This salt is obtained by dissolving tin in about four times its weight of muriatic acid. The solution is colourless, and yields when evaporated needle-shaped crystals, soluble in water, and somewhat deliquescent. Their specific gravity is 4·2932.† Water, when poured on it in small quantity, readily decomposes it; a submuriate precipitates, while a supermuriate remains in solution.

Deoxidizes metals;

This salt has a strong affinity for oxygen, and absorbs it with avidity from the air, and from nitric acid, and is converted into permuriate of tin, as Pelletier first observed. It absorbs oxygen also from arsenic acid, and arsenious acid. When these bodies are treated with muriate of tin, they are precipitated, completely deprived of oxygen, in the state of a black powder. Molybdic acid and yellow oxide of tungsten, or their combinations, when dropped into a solution of muriate of tin, immediately assume a blue colour, being changed into oxides with a minimum of oxygen. The red oxide of mercury, the black oxide of manganese, the white oxide of antimony, the oxides of zinc and of silver, are likewise deprived of their oxygen by this salt, and reduced to the metallic state. The oxygenized salts of iron and copper are also reduced to salts with a minimum of oxygen, and the muriate of gold occasions a purple precipitate, consisting of gold reduced to the state of purple oxide. For these interesting results we are indebted to Pelletier and Proust. They afford a sufficient key to explain all the singular changes produced upon the greater number of metallic salts by this muriate.‡

Muriate of copper.

28. *Muriate of copper.* Muriatic acid, while cold, does not act on copper in close vessels, though in an open vessel it gradually corrodes and dissolves it. When heated it readily oxidizes and dissolves the metal, while at the same time hydrogen gas is evolved, and part of the acid volatilized. By this process the copper is oxidized to a maximum. But muriatic acid is also capable of combining with the first oxide of

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* Ann. de Chim. xxxi. 3.

† Hassenfratz, Ann. de Chim. xxviii. 12.

‡ Pelletier, Ann. de Chim. xii. 225.—Proust, Jour. de Phys. li. 173.

copper, and of forming another salt, first discovered by M. Proust, and afterwards more precisely examined by M. Chenevix.

1. Permuriate,

(1.) *Permuriate of copper.* This salt may be obtained either by dissolving copper in muriatic acid by the assistance of heat, or by throwing the oxide of copper into that acid cold. The solution, which is of a fine green colour, yields, when sufficiently concentrated, and allowed to cool slowly, crystals of permuriate of copper in the form of rectangular parallelopipeds of a fine grass-green colour.

This salt is exceedingly acrid and caustic. Its specific gravity is 1·6776.* It is very soluble in water; and when exposed to the air, very soon attracts moisture, and is converted into a liquid of the consistence of oil. At a moderate heat it melts, and assumes a solid form when cold. Its composition is as follows:

Acid	40·2†	40·93‡
Peroxide	59·8	59·07
	100·0	100·00

The crystals, according to Proust, contain 36 per cent. of water.§ If so, they are a compound of 1 atom anhydrous salt + 8 atoms water.

This salt may be distilled to dryness without alteration; but if the heat be increased, chlorine passes over, the copper loses part of its oxygen, and there remains behind protomuriate of copper. When potash is poured into the solution of permuriate of copper, a green powder is precipitated, which is a subpermuriate, containing 72 parts in the hundred of brown oxide of copper. When copper is dissolved in nitro-muriatic acid, a similar green powder separates. Its constituents are

Acid	14·36‖	13·35**
Peroxide	85·64	86·65
	100·00	100·00

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Berzelius, Ann. de Chim. lxxviii. 119.

‡ Theoretical composition, on the supposition that it is composed of 3 atoms acid and 2 atoms oxide, or that it is a *sesquimuriate.*

§ Ann. de Chim. xxxii. 47.

‖ Berzelius, Ann. de Chim. lxxviii. 121.

** Theoretical composition, on the supposition that it is a subtritomuriate, or a compound of one atom acid and three atoms peroxide.

Permuriate of copper is not decomposed by sulphuric or nitric acid; but the alkalies and alkaline earths precipitate the oxide in the state of a subsalt, if the muriate of copper predominate; and in the state of a hydrate if the alkalies predominate.*

2. Proto-muriate.

(2.) *Muriate of copper.* This salt, which contains copper combined with a minimum of oxygen, was discovered by M. Proust, while engaged in his experiments on tin. He observed, that when the salts of copper were mixed with the muriate of tin, that the last salt deprived the copper of part of its oxygen, and formed a salt of a white colour, not acted on by sulphuric acid, but soluble in muriatic acid. This solution yielded him a colourless salt, which, on examination, proved to be a muriate of copper.†

Formation.

M. Chenevix has discovered a very simple process for obtaining this salt. He mixed together, in a mortar, 57·5 parts of the black oxide of copper, and 50 parts of copper in the state of a fine powder, obtained by precipitating that metal from its solution in muriatic acid by means of a plate of iron. The mixture was put along with muriatic acid into a well-stopped phial. A violent disengagement of caloric took place, the liquor became of a red orange colour, and the whole was dissolved except 7·5 of metallic copper. The solution consisted entirely of muriate of copper.‡

It may be obtained also, as Proust has shown, by distilling permuriate of copper. After the greatest part of the water has passed over, the acid attracts oxygen from the metal, and passes over partly in the state of chlorine; a grey mass remains in the retort, which, when dissolved, is muriate of copper. The salt may be obtained also by keeping a plate of copper plunged in a bottle filled with muriatic acid. Crystals of muriate gradually form upon the plate; and when the colourless acid is diluted with water, muriate of copper precipitates in the state of a white powder.§

This salt crystallizes in tetrahedrons. When its concentrated solution is diluted with water, the salt precipitates in the state of a white powder, being no doubt deprived of the excess of acid which held it in solution. When repeatedly washed with water, its acid is carried off, and the orange

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* Ann. de Chim. xxxii. 47.

† Ann. de Chim. xxviii. 218.

‡ Phil. Trans. 1801, p. 237.

§ Jour. de Phys. li. 181.

oxide of copper only remains.* The constituents of this salt are as follows:

Acid	26·42†	25·51‡
Protoxide	73·58	74·49
	100·00	100·00

When this salt is exposed to the air, it very speedily attracts oxygen, and is converted into permuriate of copper. The sulphate of iron, when dropped into a solution containing it, precipitates the copper in the metallic state, while it passes itself to the state of persulphate.§

It dissolves in ammonia, and forms a colourless solution, which gradually attracts oxygen when exposed to the air, and at the same time acquires a fine blue colour.||

Of mercury, 29. *Muriate of mercury.* We are not acquainted with any such salt. Calomel and corrosive sublimate are chlorides of mercury, and have been described as such. See vol. i. p. 483.

Of silver, 30. *Muriate of silver.* Neither do we know any muriate of silver. Horn-silver is a chloride, and has been described already. See vol. i. p. 496.

Of gold, 31. *Muriate of gold.* This salt, which was well known to the alchymists, and much valued by them, may be formed by dissolving gold in a mixture composed of one part of nitric and four parts of muriatic acid. The metal is attacked instantly, and dissolves with a strong effervescence, occasioned by the emission of nitrous gas. The liquid, when saturated, which is known by its refusing to dissolve more gold, forms a solution of a deep yellow colour. It tinges the skin indelibly of a deep purple colour, and produces the same effect upon almost all animal and vegetable bodies, and even upon marble. The colour is owing to the partial reduction of the yellow oxide of gold, and its permanency to the strong affinity between metallic oxides and the epidermis.

When this solution is evaporated, muriate of gold is ob-

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* Chenevix, Phil. Trans. 1801, p. 230. Though this compound is probably, or certainly, a chloride of copper, I have thought it best to give the account of it as it was drawn up by the original experimenters.

† Berzelius, Ann. de Chim. lxxviii. 118.

‡ Theoretical composition, on the supposition that it is a subsesquimuriate, or a compound of 2 atoms acid and 3 atoms protoxide.

§ Proust, Ann. de Chim. xxviii. 220.

|| Proust, Jour. de Phys. li. 182.

tained in small crystals of a fine yellow colour, having the form of four-sided prisms or truncated octahedrons. They are obtained more readily if the solution be evaporated to half its bulk, and a little alcohol be afterwards added to it. This muriate is so liquifiable, so difficult to obtain dry, that it can be scarcely taken out of the retort without considerable loss. In summer it becomes liquid in the morning, and crystallizes towards evening, passing through this alternation during the continuance of the hot weather. Its taste is acerb with a little bitterness, but without that aftertaste of metal which renders the solutions of silver, mercury, &c. so disagreeable. It dissolves readily in alcohol, and may be separated by distillation without undergoing any change.*

When its solution is heated gradually in a retort, there passes over chlorine; and a minute quantity of muriate of gold is also carried along with it undecomposed.† The gold remains spongy, and without lustre at the bottom of the retort.

This salt is soluble in ether. The solution has a yellow colour; and the gold is gradually reduced to the metallic state, doubtless by the action of the ether on it. Ether seems to dissolve muriate of gold more readily than water; for when liquid muriate of gold is agitated with ether, the whole salt passes from the water to the ether.

It is decomposed by the alkaline earths; the yellow oxide of gold being separated. But ammonia re-dissolves this oxide, and so do the fixed alkalies if added in sufficient quantity, forming probably triple salts which have not been examined.

Decomposed by combustibles.

It is decomposed also while liquid by hydrogen gas, phosphorus, and sulphurous acid; and the gold is precipitated in the metallic state, being deprived of its oxygen by these combustible bodies: but when dry this decomposition does not happen. For these very interesting facts we are indebted to the ingenious Mrs. Fulhame. She found, that when a piece of silk, dipped in a solution of gold in nitro-muriatic acid, is exposed to hydrogen gas while moist, the gold is instantly reduced; but if the silk be dried previously, the reduction does not take place. The same reduction takes place when the silk is dipped into phosphuretted ether. If a bit of silk, moistened with phosphuretted ether, be dipped into the nitro-

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* Proust, Nicholson's Jour. xiv. 239.

† To the liquid obtained by distilling over the solution of gold in nitro-muriatic acid, the alchymists gave the name of *leo rubeus*, "red lion."

muriatic solution, its surface is immediately gilt with a fine coat of gold, which adheres very strongly.

Mrs. Fulhame ascertained, that this reduction of the gold does not happen in any case unless the salt be moistened with water: when perfectly dry, it is not altered. This is not peculiar to the action of combustibles on metallic salts: it holds also, as we shall see afterwards, with respect to the metals. But it is by no means easy to see what makes water so indispensably necessary. It is not, as is commonly supposed, in order to secure the fluidity of the mixture: for Mrs. Fulhame has shown that ether, though a liquid, has no effect in reducing gold unless water be present. She accounts very ingeniously for the phenomena, by supposing that the water is decomposed. The combustible combines with its oxygen, while its hydrogen combines with the oxygen of the gold, and reproduces water. This theory accounts very well for the phenomena; but it would require some direct proof to establish it completely.

Precipitated by metals.

The greater number of the metals, when plunged into the solution of muriate of gold, occasion a precipitate either of gold in the metallic state, or of its purple oxide; while at the same time a portion of the precipitating metal is oxidized and dissolved by the acid. Zinc, iron, bismuth, copper, and mercury, precipitate it in the metallic state. Lead, silver, and tin, precipitate it in the state of purple oxide. The sulphate of iron precipitates it in the metallic state, and is at the same time converted into persulphate by the oxygen which it has absorbed; whereas the persulphate of iron produces no effect at all. The same thing happens with tin. The muriate of that metal precipitates the gold in the state of purple oxide, combined with oxide of tin; a precipitate well known by the name of *precipitate of Cassius*, and used to give a red colour to porcelain and glass: but the permuriate of tin, which is already at a maximum of oxygen, produces no such effect: because it does not absorb oxygen from the gold.

M. Proust has published a number of experiments on the *purple of Cassius*. He has endeavoured to prove that it is a compound of gold in the metallic state, and the peroxide of tin. His proofs that the gold is in the metallic state, do not appear to me to be quite convincing, though they certainly render the opinion plausible. There can be no doubt that the two constituents of this powder are chemically combined. When the liquid, from which purple of Cassius is precipitated, contains an excess of acid, the precipitation goes on very slowly. It is very much facilitated by the addition of potash; but care should be taken not to add this alkali in excess, otherwise the precipitate is contaminated with a mixture of uncombined oxide of tin. From Proust's experiments we learn, that this powder is a compound of one part of gold and three parts of peroxide of tin.* Aqua regia dissolves the gold and leaves the tin; on the other hand, muriatic acid dissolves the tin and leaves the gold. Nitric acid dissolves a portion of the tin, and brightens the colour of the powder; but is not capable of dissolving the whole.

Muriate of platinum.

32. *Muriate of platinum.* This salt may be formed by dissolving platinum in chlorine; but it is more easily obtained by means of nitro-muriatic acid. Sixteen parts of a mixture, composed of one part of the strongest nitric and three parts of muriatic acids, when boiled upon platinum previously reduced to powder, gradually dissolve it with a violent effervescence, during which chlorine gas is disengaged. This solution assumes at first a yellow colour, which gradually deepens as the platinum dissolves; and when the solution is finished, it is of a very deep red or brown. It is exceedingly acrid and caustic, and tinges the skin indelibly of a dark brown colour. When it is sufficiently concentrated by evaporation, very small irregular crystals of muriate of platinum are deposited of a reddish-brown colour: when properly edulcorated and dried, they are less soluble in water than sulphate of lime.† This salt has a disagreeably astringent metallic taste. Heat decomposes it by driving off the acid. The earths, as far as they have been tried,‡ decompose the solution of this salt by precipitating its oxide: and the same effect, as Bergman first demonstrated, is produced by a sufficient quantity of soda.§ But the other two alkalies combine with the muriate of platinum, and form triple salts.

When the solution of this salt is evaporated to dryness, the insoluble muriate which remains is composed of

70 peroxide of platinum
30 acid and water

100 ‖

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* Nicholson's Journal, xiv. 336 † Bergman, ii. 167.

‡ M. Chenevix found that lime precipitates only a portion of the oxide, and not the whole.

§ Bergman, p. 172. ‖ Chenevix on Palladium, p. 27.

Muriatic acid destroys putrid miasmata.

V. Morveau first showed that muriatic acid, in the state of gas, neutralizes putrid miasmata, and by that means destroys their bad effects. In 1773, the cathedral of Dijon was so infected by putrid exhalations, that it was deserted altogether after several unsuccessful attempts to purify it. Application was made to M. Morveau, at that time Professor of Chemistry at Dijon, to see whether he knew any method of destroying these exhalations. Having poured two pounds of sulphuric acid on six pounds of common salt, contained in a glass capsule, which had been placed on a few live coals in the middle of the church, he withdrew precipitately, and shut all the doors. The muriatic acid gas soon filled the whole cathedral, and could even be perceived at the door. After twelve hours, the doors were thrown open, and a current of air made to pass through to remove the gas. This destroyed completely every putrid odour.*

SECT. II.

OF CHLOROCARBONIC ACID.

This acid was discovered by Dr. John Davy in 1812. He gave it the name of *phosgene gas.* I have given an account of its properties in a former part of this work.† It has been hitherto so imperfectly examined that the few facts ascertained respecting it found a place under the head of *carbon.* It is the only acid at present known which is formed of two supporters united to a simple combustible. Many of the bases decompose it. But it is possible that it might unite with the chlorides and form a class of salts altogether new.

SUBDIVISION III.

COMPOUNDS OF IODINE WITH SUPPORTERS AND COMBUSTIBLES.

Iodine having been known to chemists only for a very few years, it is not surprising that the compounds which it forms have been hitherto but imperfectly investigated. Three chap-

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* Jour. de Phys. i. 436.

† See vol. i. p. 233.

ters will exhaust all that we know at present of these bodies. In the first we shall describe the combinations of iodine with simple supporters, in the second the *iodides*, and in the third the acids formed by the union of iodine with simple combustibles.

CHAP. I.

OF THE COMPOUNDS OF IODINE WITH SUPPORTERS.

Iodine is capable of combining both with oxygen and chlorine, and with each of these bodies it forms an acid. The compound of iodine and oxygen is called *iodic acid*, the compound of iodine and chlorine *chloriodic acid*. These two acids will occupy our attention in the two following sections.

SECT. I.

OF IODIC ACID.

This acid in a separate state was first discovered and described by Sir H. Davy. I have given an account of its properties and constitution in a former part of this work.* But the compounds which it forms with acids and with the salifiable bases still remain to be described.

I. The compounds which it forms with the acids were discovered by Sir H. Davy.† They have not hitherto been distinguished by any name, though there seems no reason to doubt that they are real chemical combinations.

Compounds with

1. When sulphuric acid is dropped into a concentrated solution of iodic acid, a solid substance precipitates, consisting of the two acids united together. When heated this substance melts, and on cooling forms rhomboidal crystals of a pale yellow colour, which are very fusible, and which do not alter at the temperature in which iodic acid is decomposed. When strongly heated it is partly sublimed and partly decomposed into oxygen, iodine, and sulphuric acid.

Sulphuric acid,

2. With phosphoric acid, iodic acid forms a solid, yellow, crystalline compound, the formation of which is attended with similar phenomena.

Phosphoric acid,

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* See vol. i. p. 192.

† Phil. Trans. 1815, p. 204.

Nitric acid,

3. When nitric acid is poured into a concentrated solution of iodic acid, white crystals are deposited, having the form of rhomboidal plates. When dried they are partly sublimed and partly decomposed into oxygen, iodine, and nitric acid.

Boracic acid,

4. Boracic acid may be dissolved in concentrated iodic acid by the assistance of heat. When the solution is evaporated, a solid white substance is obtained, not so easily decomposed by heat as iodic acid itself.

Phosphorous and oxalic acids.

5. Phosphorous acid and oxalic acid dissolve in concentrated iodic acid, but when the solution is heated the iodic acid is decomposed, and phosphoric acid or carbonic acid formed. Muriatic acid immediately decomposes iodic acid, and chloriodic acid is formed.

Compounds with bases,

II. The existence of compounds of iodic acid and salifiable bases, or of *iodates*, as they are now called, seems to have been ascertained about the same time, both by Sir H. Davy and by Gay-Lussac; but it was Davy that published the first account of them.

Iodate of ammonia,

1. *Iodate of ammonia.* This salt may be obtained by saturating iodic acid with ammonia. It crystallizes in small grains, the form of which has not been ascertained. When thrown upon burning coals it detonates with a hissing noise, emitting a weak violet light, and giving out vapours of iodine. When decomposed by heat, a mixture of azote and oxygen gases are evolved.* If we suppose it a compound of 1 atom iodic acid + 1 atom ammonia, its constituents by weight will be

Iodic acid	20·625	100
Ammonia	2·125	10·30

Of potash,

2. *Iodate of potash.* This salt is easily obtained by dissolving iodine in potash ley. A colourless solution is obtained which lets fall a white powder, consisting chiefly of *iodate of potash.* By digesting it in alcohol, the small quantity of *hydriodate* with which it is mixed may be dissolved away, and the iodate obtained in a state of purity. Its crystals are so small that their figure has not hitherto been ascertained. This salt is not altered by exposure to the air. One hundred parts of water at 57½° dissolve 7·43 parts of this salt. When heated to redness, oxygen gas is disengaged and iodide of potassium remains: on burning coals it fuses and deflagrates like nitre.† This salt is composed of

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* Gay-Lussac, Ann. de Chim. xci. 80.

† Ibid. 74.

Iodic acid	20·625	100
Potash	6·000	29·09

Of soda.

3. *Iodate of soda.* This salt may be obtained by the same process as the preceding one. It crystallizes in small prisms united together in tufts. Gay-Lussac obtained it in small cubes. One hundred parts of water at the temperature of 57½° dissolve 7·3 parts of it. When heated sufficiently it gives out 24·45 per cent. of oxygen gas, and iodide of sodium remains behind. On burning coals it fuses and deflagrates like nitre. Like the preceding salt it detonates feebly when mixed with sulphur and struck upon an anvil.* It is composed of

Iodic acid	20·625	100
Soda	4·000	13·29

When iodine is dissolved in soda lye till the liquid begins to become coloured, the solution yields when evaporated fine crystals in six-sided prisms terminated by flat hexahedrons perpendicular to the axis of the crystal. These crystals are very soluble and contain much water of crystallization. Their nature has not been determined. Gay-Lussac considers them as a subiodate of soda; but this opinion is not very probable. A subiodate of soda exists, indeed, but it crystallizes in needles.

Of lime.

4. *Iodate of lime.* This salt may be obtained by dissolving carbonate of lime in iodic acid, or by mixing a salt with base of lime and iodate of potash. It is usually in powder; but it may be obtained in crystals, by dissolving it in the solution of muriate or hydriodate of lime. Its crystals are small quadrangular prisms. One hundred parts of boiling water dissolve 0·98 of this salt; 100 parts of water at the temperature of 64½° dissolve 0·22 of it. The phenomena which take place when it is exposed to heat are similar to those which appear when iodate of potash is heated, excepting only that iodate of lime requires a stronger heat to decompose it. Its water of crystallization amounts to about 3 per cent.† The constituents of this salt are,

Iodic acid	20·625	100
Lime	3·625	17·57

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* Gay-Lussac, Ann. de Chim. xci. 74.

† Ibid. 84.

Of barytes, 5. *Iodate of barytes.* This salt is obtained easily by a similar process as the last. It precipitates in powder and becomes farinaceous in drying. It cannot be deprived of the whole of its water by exposure to a temperature equal to that of boiling water. When heated sufficiently it is decomposed into oxygen, iodine, and barytes. One hundred parts of boiling water dissolve 0·16 of this salt; 100 parts of water at 63½° dissolve only 0·03 of it. On burning coals it does not fuse and scarcely deflagrates.* Its constituents are,

Iodic acid	20·625	100
Barytes	9·75	47·27

Of strontian, 6. *Iodate of strontian.* This salt is obtained in the same way as the preceding. It forms small crystals which, when viewed by the microscope, appear to be octahedrons. One hundred parts of boiling water dissolve 0·73 of this salt; 100 parts of water at 59° dissolve only 0·24 of it. It contains water of crystallization. When exposed to heat it exhibits exactly the same phenomena as iodate of barytes.† Its constituents are,

Iodic acid	20·625	100
Strontian	6·5	31·51

Of zinc, 7. *Iodate of zinc.* This salt may be formed by dissolving carbonate of zinc in iodic acid. It may be procured also by mixing with a soluble iodate a solution of sulphate of zinc, not too much concentrated. After an interval of some hours the iodate of zinc precipitates in spherical grains. This salt is but little soluble in water. It deflagrates on coals, but much more feebly than iodate of potash.‡

Of silver, 8. *Iodate of silver.* This salt may be formed by mixing a solution of nitrate of silver with iodate of potash. The iodate of silver precipitates. This salt is soluble in ammonia. Hence by ammonia we can separate iodide of silver, chloride of silver, and iodate of silver from each other. Ammonia dissolves the two last, but does not touch the first of these bodies. When sulphurous acid is added to the solution, the iodate of silver is changed into iodide, and thus becomes insoluble in ammonia; it therefore precipitates, and nothing remains in solution but chloride of silver.§

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* Gay-Lussac, Ann. de Chim. xci. 81.

† Ibid. 84.

‡ Ibid. 85.

§ Ibid. 84.

9. Nitrate of silver, protonitrate of mercury, persulphate of iron, nitrate of bismuth, and sulphate of copper, give with iodate of potash, precipitates which are soluble in acids. Pernitrate of mercury, and sulphate of manganese, are not precipitated by this salt.*

The remaining iodates still continue unknown, not having hitherto been examined by chemists.

SECT. II.

OF CHLORIODIC ACID.

This acid has been described at sufficient length in a former part of this work.† It does not appear capable of combining with bases. Whenever a base was presented to it, water was always decomposed, and muriatic acid and iodic acid formed.

CHAP. II.

OF IODIDES.

In the present state of our knowledge of these bodies, I thought it better to describe them while treating of their different bases. An account, therefore, of all of them with which we are acquainted will be found in the chapter on simple combustibles.

CHAP. III.

OF ACIDS COMPOSED OF IODINE AND A COMBUSTIBLE.

We are acquainted with only one acid formed by the union of iodine and a combustible; namely, *hydriodic acid*, composed of iodine and hydrogen. This acid will constitute the subject of the following section.

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* Gay-Lussac, Ann. de Chim. xci. p. 86

† See vol. i. p. 194.

SECT. I.

OF HYDRIODIC ACID.

Book II. Division I.

THIS acid seems to have been discovered by M. Clement. But for the investigation of its properties we are indebted to Davy and Gay-Lussac. The easiest method of preparing it is to put a quantity of iodine into water, and to cause a current of sulphuretted hydrogen gas to pass through the liquid. The hydrogen of the gas unites with the iodine while the sulphur is precipitated. When the whole of the iodine is dissolved, allow the liquid to remain at rest for some time till the sulphur is deposited, then decant off the clear liquid. By heating the liquid the excess of sulphuretted hydrogen may be driven off, and by cautious evaporation it may be considerably concentrated.

The properties and constitution of hydriodic acid having been described in a previous part of this work,* it remains for us at present to describe the compounds which it forms by uniting with the different bases. The composition of these compounds is easily determined by recollecting that the weight of an atom of hydriodic acid is 15·75, and that in each compound this weight of acid unites with the weight of each base which is given in the last column of the table, printed in vol. i. p. 542 of this work.

Hydriodate of ammonia,

1. *Hydriodate of ammonia.* This salt is formed when equal volumes of *hydriodic acid* and *ammonaical gas* are mixed together. The easiest way of obtaining it is to dissolve liquid ammonia in hydriodic acid. It crystallizes in cubes. It is very soluble in water and deliquesces when exposed to the air. It may be sublimed in close vessels without decomposition. But in the open air it is partially decomposed when sublimed, and it becomes coloured. But it may be rendered colourless again by exposure to the open air, or by the addition of a little ammonia.† Its constituents are,

Hydriodic acid	15·75	100
Ammonia	2·125	13·49

Of potash,

2. *Hydriodate of potash.* Hydriodic acid dissolves carbonate of potash with effervescence, and the saturated solu-

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[*] See vol. i. p. 223.

[†] Gay-Lussac, Ann. de Chim. xci. p. 62.

tion may be considered as a liquid hydriodate of potash. But when we attempt to separate it in crystals, it is converted into iodide of potassium, and in that state separates in cubes similar in appearance to common salt. That this decomposition actually takes place is evident from the following experiment of Gay-Lussac. He dissolved a given weight of iodide of potassium in water, and then separated it in crystals, the weight of the iodide was not altered.* The constituents of this salt are as follows:

Hydriodic acid	15·75	100
Potash	6	38·09

Of soda,

3. *Hydriodate of soda.* This salt may be formed in the same way as the preceding. It crystallizes in flat rhomboids, which uniting together form larger crystals somewhat similar to those of sulphate of soda. It contains much water of crystallization, and notwithstanding is very deliquescent. When dried it must be considered as an iodide of sodium.† Its constituents are,

Hydriodic acid	15·75	100
Soda	4	25·39

Of lime,

4. *Hydriodate of lime.* This salt is obtained in a state of purity by saturating hydriodic acid with carbonate of lime. It is very soluble in water and very deliquescent. It may be dried in the air without undergoing decomposition.‡ Its constituents are,

Hydriodic acid	15·75	100
Lime	3·625	23·01

Of barytes,

5. *Hydriodate of barytes.* This salt crystallizes in fine prisms similar in appearance to muriate of strontian. It is very soluble in water and but feebly deliquescent. When long exposed to the air, a portion of the hydriodic acid is decomposed and dissipated, carbonate of barytes is formed, and hydriodate of barytes coloured by iodine may be dissolved by water. In close vessels it may be heated to redness without undergoing any alteration. But if air or oxygen gas have access to it while red hot, vapours of iodine are exhaled, and

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* Ann. de Chim. xci. p. 54

† Gay-Lussac, p. 55.

‡ Ibid. p. 60.

the salt becomes alkaline. By a red heat this salt is converted into iodide of barium.* Its constituents are,

Hydriodic acid	15·75	100
Barytes	9·75	61·90

Of strontian,

6. *Hydriodate of strontian.* This salt is very soluble in water. It fuses when heated to a temperature rather below redness. This fusion produces little alteration in close vessels; but in the open air vapours of iodine are exhaled, and the salt becomes alkaline. There can be no doubt that by fusion in close vessels it is converted into iodide of strontium.† The constituents of this salt are,

Hydriodic acid	15·75	100
Strontian	6·5	41·20

Of magnesia,

7. *Hydriodate of magnesia.* This salt is deliquescent and crystallizes with difficulty. When heated to redness, out of the contact of air, the acid flies off and leaves the magnesia.‡ Its constituents are,

Hydriodic acid	15·75	100
Magnesia	2·5	15·87

Of zinc.

8. *Hydriodate of zinc.* This salt is easily obtained by heating iodine with an excess of zinc under water. The liquid at first acquires a deep brown colour; but if we continue the heat, more zinc is dissolved, and the whole becomes at last as colourless as water. It cannot be crystallized by evaporation. But if it be evaporated to dryness and fused, it crystallizes in beautiful prisms similar to those of white oxide of antimony. When thus heated, it is converted into iodide of zinc. When heated in the open air it is decomposed, the acid is driven off under the form of iodine, and oxide of zinc remains.§ The constituents of this salt are as follows:

Hydriodic acid	15·75	100
Oxide of zinc	5·125	32·53

9. Hydriodate of potash does not precipitate solutions of manganese, nickel, or cobalt. Hence the hydriodates of these metals are soluble in water. Gay-Lussac is of opinion that all the hydriodates of the metals, capable of decomposing

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* Gay-Lussac, Ann. de Chim. xci. p. 57.

† Ibid. p. 60.

‡ Ibid. p. 63.

§ Ibid. p. 65.

water, possess solubility. But the solutions of the metals, incapable of decomposing water, are precipitated by hydriodate of soda.

The precipitate of copper is *greyish white;* that of lead a fine *orange yellow;* that of protoxide of mercury *greenish yellow;* that of peroxide of mercury *orange red;* that of silver is *white;* that of bismuth *morone.*[*]

SUBDIVISION IV.

OF COMPOUNDS OF FLUORINE WITH SUPPORTERS AND COMBUSTIBLES.

Fluorine not having been hitherto obtained in an uncombined state, we are much less perfectly acquainted with the compounds which it is capable of forming with other bodies, than with similar combinations of chlorine or even of iodine. We do not know whether it be capable of uniting with the other supporters of combustion, and of forming acids with them, as is the case with oxygen, chlorine, and iodine. Analogy leads us to suppose that such a class of bodies as *fluorides* must exist, though hitherto not one of them has been formed and examined. We know, at present, only three compounds of fluorine and three combustible bodies, all of which possess acid properties. This subdivision then will contain, in the present state of our knowledge, only one chapter.

CHAP. I.

OF ACIDS COMPOSED OF FLUORINE AND A COMBUSTIBLE.

The three combustible bodies with which fluorine combines are, *hydrogen*, *boron*, and *silicon*, and united with each it constitutes a powerful acid. These acids are the *fluoric*, the *fluoboric*, and the *fluosilicic*. They will constitute the subject of the three following sections.

Gay-Lussac, Ann. de Chim. xci. p. 66.

SECT. I.

OF FLUORIC ACID.

Book II. Division I.

History.

THE mineral called *fluor* or *fusible spar*, and in this country *Derbyshire spar*, was not properly distinguished from other spars till Margraff published a dissertation on it in the Berlin Transactions for 1768. He first proved that it contained no sulphuric acid as had been formerly supposed; he then attempted to decompose it by mixing together equal quantities of this mineral and sulphuric acid, and distilling them. By this method he obtained a *white sublimate*, which he supposed to be the fluor itself volatilized by the acid. He observed with astonishment that the glass retort was corroded, and even pierced with holes. Nothing more was known concerning fluor till Scheele published his experiments three years after; by which he proved that it is composed chiefly of lime and a particular acid, which has been called *fluoric acid.*

As Scheele always employed glass vessels in his experiments, he obtained not *fluoric* acid, but *fluosilicic* acid. It was this last acid, likewise, that Dr. Priestley investigated in the gaseous state. Real fluoric acid remained unknown till its properties were investigated by Gay-Lussac and Thenard, in 1808.* The subject was resumed by Dr. John Davy, who added some important facts in 1812.† Sir H. Davy examined it in 1813 with much sagacity, in order to verify, if possible, the hypothesis of Ampere, respecting its nature.‡

In a former part of this work I have described the method of obtaining this acid in a state of purity, given an account of its properties, and stated the reasons for considering it as a compound of 1 atom fluorine and 1 atom of hydrogen. It remains for us, in this place, to give an account of the compounds which fluoric acid makes with the different bases. None of these *fluates*, as they are called, have been hitherto analyzed; but an idea may be formed of their constitution by considering the weight of an atom of fluoric acid to be 2·125, and by supposing the fluates compounds of 1 atom fluoric acid and 1 atom of each of the different salifiable bases.

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* Recherches Physico-chimiques, ii. p. 1.

† Phil. Trans. 1812, p. 352.

‡ Ibid. 1813, p. 263.

Fluate of ammonia,

1. *Fluate of ammonia.* This salt may be formed by saturating pure fluoric acid with ammonia. While in a liquid state, it is neutral; but when evaporated, it becomes acid in consequence of the escape of a portion of the ammonia. It does not crystallize, but when heated may be volatilized in thick white vapours. It precipitates the solutions of all the alkaline earths, and earths proper, in acids, because fluoric acid forms insoluble compounds with all the earths.*

Of potash,

2. *Fluate of potash.* When pure potash is poured into fluoric acid, a combination takes place with the evolution of much heat. This salt has a very sharp taste, crystallizes with difficulty, is very deliquescent, and of course very soluble in water. When heated it undergoes first the aqueous, and then the igneous fusion. Sulphuric acid decomposes it, driving off fluoric acid in vapour. All the earthy salts precipitate its acid in combination with their bases.†

Of soda,

3. *Fluate of soda.* This salt may be formed by the same process as the preceding. It has much less taste than fluate of potash. When heated it decrepitates and undergoes the igneous fusion. It is not altered by exposure to the air. It is rather more soluble in hot than in cold water. It separates on cooling in small crystals, or more frequently forms a solid and transparent crust on the surface of the water. It is decomposed by the earthy salts and by sulphuric acid precisely like fluate of potash.‡

Of lime.

4. *Fluate of lime.* This salt exists abundantly native. It is from it indeed that fluoric acid is always extracted.

It is found frequently crystallized. The primitive form of its crystals, according to Haüy, is the octahedron, but it occurs more frequently in cubes; sometimes the angles, and sometimes the edges of these cubes, are truncated. The form of its integrant particles is the regular tetrahedron.

This salt has no taste. Its specific gravity is 3·15. It is insoluble in water, and not altered by exposure to the air.

Phosphoresces.

When heated, it decrepitates and phosphoresces strongly in the dark. It emits this light even under water, or in the vacuum of an air pump. When kept hot for some time, it ceases to shine, and the phosphorescent property cannot be again restored to it by any process known, except by decomposing it altogether by means of sulphuric acid, and forming it anew.

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* Gay-Lussac and Thenard, Recherches Physico-chimiques, ii. p. 23.

† Ibid. p. 18.

‡ Ibid. p. 21.

Scheele ascertained that new-formed fluate of lime is equally phosphorescent with native. The cause of this curious property is not well understood. After being heated, the salt, though it refuses to phosphoresce any more, has not lost any perceptible weight, nor is it altered in any of its other qualities. When strongly heated, fluate of lime melts into a transparent glass. According to Saussure, this takes place at the temperature of 51° Wedgewood.*

We must consider this compound as in reality a *fluoride of calcium*, or a compound of fluorine and calcium. According to Davy's analysis corrected by the hypothesis of its being a fluoride, its constitution is

Fluorine	2	100
Calcium	2·625	131·25

Of barytes. 5. *Fluate of barytes.* This salt is easily obtained by dropping fluoric acid into barytes water. White flocks precipitate, which constitute the fluate in question. It is tasteless, insoluble in water; but soluble in an excess of fluoric acid, and likewise in nitric and muriatic acid.† There can be little doubt that this compound is in reality a fluoride of barium. On that supposition it will be composed of

Fluorine	2	100
Barium	8·75	437·5

6. *Fluate of strontian.* This salt may be formed in the same way as the preceding, and possesses the very same properties. It is a white powder, insoluble in water, but soluble in fluoric acid, and likewise in nitric and muriatic acids.‡

Of magnesia, 7. *Fluate of magnesia.* Carbonate of magnesia dissolves with effervescence in fluoric acid. The fluate is a tasteless white powder, insoluble in water, and scarcely soluble in acids. When this salt is formed by pouring fluate of potash into sulphate of magnesia, it precipitates at first in a gelatinous form, and is then soluble in acids; but as soon as it dries it becomes insoluble in these bodies.§

Of yttria, 8. *Fluate of yttria.* This salt may be formed by dropping fluate of potash into muriate of yttria. It is a white tasteless powder, totally insoluble in water.||

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* Jour. de Phys. xlv. 16.

† Gay-Lussac and Thenard; Recherches Physico-chimiques, ii. 24.

‡ Ibid. ii. 25.

§ Ibid. p. 26.

|| Ibid. p. 29.

9. *Fluate of glucina.* This salt may be formed in the same way as the preceding. A jelly precipitates, which dissolves in hot-water, and precipitates in small crystals as the liquid cools.[*]

Of alumina.

10. *Fluate of alumina.* This salt may be obtained by pouring fluate of potash into a solution of alum. Fluate of alumina precipitates in a white powder. It is insoluble in water, but soluble in an excess of acid. After being well dried the acids attack it with difficulty.[†]

Cryolite.

11. *Soda-fluate of alumina.* This curious compound has been found native in Greenland, and described by mineralogists under the name of *cryolite.* It has the appearance of a stone.

Its colour is greyish white; it has some transparency; when broken its fragments are cubical. It is softer than fluor spar, brittle, and of the specific gravity 2·950. Before the blowpipe it melts. According to the analyses of Klaproth and Vauquelin it is composed of

Acid and water	40	47
Soda	36	32
Alumina	24	21
	100[‡]	100[§]

Fluate of zirconia.

12. *Fluate of zirconia.* This salt may be obtained by dropping fluate of potash into muriate of zirconia. It is a white insoluble powder similar to the other earthy fluates.[‖]

It is exceedingly probable that all these earthy fluates are in reality *fluorides*, or combinations of fluorine with the metallic bases of the earths.

Of iron.

13. *Fluate of iron.* Fluoric acid dissolves iron but very slowly, no doubt in consequence of the insoluble nature of the fluate of iron. This salt may be easily obtained by mixing fluate of potash and sulphate of iron. The fluate precipitates in the state of a white tasteless insoluble powder.[**]

Of cobalt.

14. *Fluate of cobalt.* Oxide of cobalt may be readily dissolved in fluoric acid. The salt has a red colour and contains an excess of acid. When evaporated it deposites small red crystals which are less acid than the solution. When these

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[*] Gay-Lussac and Thenard; Recherches Physico-chimiques, ii. p. 27.

[†] Ibid.

[‡] Klaproth's Beitrage, iii. 214.

[§] Vauquelin, Haüy's Min. ii. 400.

[‖] Gay-Lussac and Thenard, Recherches Physico-chimiques, ii. 29.

[**] Ibid. p. 30.

acids are treated with water they are divided into two distinct salts, a superfluate which dissolves, and a fluate which remains in the state of a red powder.*

Of manganese, 15. *Fluate of manganese.* This salt is easily obtained by pouring fluate of potash into the sulphate or muriate of manganese. The fluate precipitates in a white powder, insoluble in water, but soluble in acids.†

Of zinc, 16. *Fluate of zinc.* Zinc dissolves readily in diluted fluoric acid. After a certain time the fluate precipitates in gelatinous flocks. It is white, tasteless, and insoluble in water. It is easily obtained by mixing fluate of potash with sulphate of zinc.‡

Of lead, 17. *Fluate of lead.* Fluoric acid has no sensible action on lead. But when the acid is dropped into a solution of acetate of lead, fluate of lead precipitates in brilliant plates. It acts feebly as an acid on paper stained with litmus. It is insoluble in water, but very soluble in nitric, muriatic, and fluoric acids. It melts when heated to redness, and becomes yellow, losing a portion of its acid. Sulphuric acid decomposes it, disengaging vapours of fluoric acid.§

Of tin, 18. *Fluate of tin.* Fluoric acid does not act upon tin, even when assisted by heat, at least when diluted with water. It readily dissolves peroxide of tin, provided there be a considerable excess of acid. When the solution is concentrated, it becomes opaque in consequence of the separation of fluate of tin. The addition of water re-dissolves the fluate almost completely. But when the solution is evaporated to dryness, the fluate of tin remains and is insoluble in water.||

Of copper, 19. *Fluate of copper.* Fluoric acid does not attack copper, but it readily dissolves the peroxide, provided there be an excess of acid. When the liquid is evaporated, small blue-coloured crystals are deposited. Sulphate of copper is not precipitated by fluate of potash, unless it constitute a concentrated solution.**

Of mercury, 20. *Fluate of mercury.* Fluoric acid does not act upon mercury; but it unites with the red oxide of mercury by means of heat, and dissolves a portion of it. When the solution is evaporated it deposites small lamellar yellow crystals. They contain an excess of acid, and by repeated affusions of water al-

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* Gay-Lussac and Thenard; Recherches Physico-chimiques, ii. 33.

† Ibid. p. 31.

‡ Ibid. p. 29.

§ Ibid. p. 34.

|| Ibid. p. 31.

** Ibid. p. 32.

most all the acid may be washed away, and the red oxide of mercury left behind.*

Of silver.

21. *Fluate of silver.* Fluoric acid readily dissolves the oxide of silver. The fluate has a strong metallic taste, is very soluble in water, and does not crystallize. It is not volatile. When heated it melts, loses its excess of acid, but still continues soluble in water. It blackens the fingers. It is precipitated by muriatic acid. All the bases precipitate the fluoric acid from it except ammonia. This salt cannot be formed by the direct action of fluoric acid on silver. But it is formed when fluate of mercury is made to act upon silver. Fluate of potash does not occasion a precipitate in nitrate of silver.†

The remaining fluates are still unknown.

SECT. II.

FLUOBORIC ACID.

THIS acid was discovered by Gay-Lussac and Thenard; but it was Sir H. Davy that first explained its real nature and composition. I have given an account of the mode of obtaining this acid, and described its properties in a preceding part of this work.‡

Composition.

When potassium or sodium is heated in fluoboric acid gas, the fluorine combines with the alkaline metal, and converts it into a fluoride, while the boron is separated. But the boron being intermixed with the solid fluoride prevents us from recognising its properties. The fluoride when dissolved in water is converted into fluate of potash or soda, while the boron is disengaged in the form of a powder.§ I consider this experiment as affording a satisfactory proof that fluoboric acid is in reality a compound of fluorine and boron. If we suppose it to contain an atom of each constituent, its composition will be

Fluorine	2	100	228·57
Boron	0·875	43·75	100

I ought here to describe the compounds formed by the union of fluoboric acid with the salifiable bases, compounds to which the name of *fluoborates* has been given. But none of these

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* Gay-Lussac and Thenard; Recherches Physico-chimiques, ii. 35.

† Ibid. p. 33.

‡ See vol. i. p. 214.

§ Gay-Lussac and Thenard; Recherches Physico-chimiques, ii. 45.

salts has been hitherto examined, except the *fluoborate of ammonia*, first formed by Gay-Lussac and Thenard, and afterwards more carefully studied by Dr. John Davy.

Fluoborate of ammonia.

Fluoboric acid and ammonia unite in three proportions; the first salt is a compound of 1 volume fluoboric acid gas, and 1 volume ammoniacal gas. Hence its constituents by weight are

Fluoboric acid ..	72·312	8·536
Ammonia	18·000	2·125

The second salt is a compound of 1 volume fluoboric acid + 2 volumes ammoniacal gas. Hence its constituents are

Fluoboric acid ..	72·312	4·268
Ammonia	36·000	2·125

The third salt is a compound of 1 volume fluoboric acid + 3 volumes ammoniacal gas. Hence its constituents are

Fluoboric acid ..	72·312	2·845
Ammonia	54·000	2·125

If fluoboric acid be a compound of 1 atom fluorine, and one atom boron, the weight of an atom of it would be only 2·875. On this supposition the third salt would be a compound of 1 atom acid + 1 atom ammonia. But this supposition is not very probable. It would indicate an uncommon condensation in fluoboric acid gas.

The first of these fluoborates of ammonia is a solid opaque substance, similar to the other ammoniacal salts. The second and third of them are liquids though they contain no water. The first may be volatilized in close vessels by the application of a gentle heat. The second and third when exposed to the atmosphere gradually give out ammonia, and are converted into the first kind.*

SECT. III.

OF FLUOSILICIC ACID.

This was the acid discovered by Scheele, and afterwards examined in the gaseous state by Dr. Priestley. I adopt the opinion of Sir H. Davy that it is a compound of fluorine and silicon; which I think corresponds much better with the phe-

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* John Davy; Phil. Trans. 1812, p. 368.

nomena than the commonly received opinion, that it is a solution of silica in fluoric acid. An account of the properties of this acid has been given in a preceding chapter of this work.* It now remains only to describe the compounds which it forms with the different salifiable bases.

Fluosilicate of ammonia,

1. *Fluosilicate of ammonia.* This salt is easily obtained by mixing its two constituents in the gaseous state. One volume of fluosilicic acid condenses two volumes of ammoniacal gas. Hence it is composed by weight of

Fluosilicic acid..	108·992	6·133
Ammonia	36	2·125

This seems to indicate a compound of 2 atoms fluosilicic acid with 1 atom of ammonia. But the data upon which the weight of an atom of fluosilicic acid is founded, are too imperfect to entitle us to put much stress on any such determinations.

Fluosilicate of ammonia is a white powder, which may be sublimed by a moderate heat in dry vessels. It is decomposed by the contact of water, part of the silicon being precipitated in the state of silica.

We are not acquainted with any other pure fluosilicates except that of ammonia. All those which I am going to describe are formed by the union of the salifiable bases to the acid dissolved in water, and of course deprived of about one-third of its silicon. It is probable that this acid is a compound of 2 atoms silicon and 2 atoms fluorine. But the subject is still so obscure that nothing better than conjecture respecting it can be offered.

Of potash,

2. *Fluosilicate of potash.* If into fluosilicic acid dissolved in water a quantity of potash, or the carbonate, sulphate, nitrate, or muriate of that alkali, be dropped, a gelatinous precipitate immediately appears, which, when dried, becomes white like chalk, and separates into small loose grains like the sand of an hour-glass. This powder is a combination of fluosilicic acid and potash. Its nature was first ascertained by Scheele.

It has an acid taste, and is soluble in about 150 parts of boiling water; but is again partly deposited as the solution cools. When strongly heated, it melts into a transparent glass, and loses its acid.†

Gay-Lussac and Thenard have likewise described this salt;‡

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* See vol. i. p. 252.

† Scheele, Crell's Annals, i. 214. Eng. Trans.

‡ Recherches Physico-chimiques, ii. 19.

but they do not seem to have been aware that it had been already examined by Scheele. When heated to redness, fluosilicic acid is disengaged. It is decomposed with effervescence by sulphuric acid. It always reddens vegetable blues, and is not deprived of this property though kept for many hours in contact with potash, soda, or ammonia. But when heat is applied, potash or soda lye dissolve this salt completely.*

Of soda, 3. *Fluosilicate of soda.* Scheele affirms that this salt may be formed in the same way as the preceding, and that it possesses exactly the same properties.† Gay-Lussac and Thenard were able only to procure common fluate of soda.‡ I am inclined to the opinion that Scheele's experiments are correct.

Of lime, 4. *Fluosilicate of lime.* This salt is very common, native, and has not been hitherto distinguished from fluor spar. It may be easily recognized by reducing a little of it to powder, and heating it in metallic vessels with sulphuric acid, as it yields fluosilicic acid gas, which pure fluor spar does not.

Of barytes. 5. *Fluosilicate of barytes.* When nitrate or muriate of barytes is poured into fluosilicic acid no immediate change takes place; but, after an interval of some minutes, the mixture becomes opaque, and a number of small hard crystals are deposited, which are insoluble in water, and in nitric and muriatic acid, and which are not altered when strongly heated with lamp black. These crystals are *fluosilicate of barytes.*§

The remaining fluosilicates still continue unknown, no attempt having been hitherto made to examine them.

SUBDIVISION V.

OF COMPOUNDS OF CYANOGEN WITH SUPPORTERS AND COMBUSTIBLES.

Cyanogen differs from the simple supporters of combustion in being a compound of 2 atoms carbon and 1 atom azote, and in being itself combustible, in consequence of the carbon which it contains. But it possesses a striking analogy with these bodies in being capable of uniting with certain supporters and

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[*] Gay-Lussac and Thenard; Recherches Physico-chimiques, ii. 19.

[†] Memoires de Chimie, i. 27.

[‡] Recherches Phys. Chim. ii. 21.

[§] Gay-Lussac and Thenard, ibid. p. 25.

combustible bodies without undergoing decomposition, and of forming with them compounds possessed of very remarkable properties. In consequence of this analogy I have placed these compounds as a sequel to those consisting of the simple supporters united to combustibles. The compounds of cyanogen and combustibles are probably numerous. Some of them are analogous to oxides, and on that account may be distinguished by the name of *cyanodides*. But those which deserve the greatest attention, in the present state of our knowledge, possess acid properties. I shall satisfy myself with describing them; and I shall notice, while giving an account of them, the few cyanodides with which we are at present acquainted. This subdivision, therefore, will be divided into two chapters. In the first I shall treat of the compounds of cyanogen with supporters; in the second, of the acid compounds of cyanogen with combustibles.

CHAP. I.

OF COMPOUNDS OF CYANOGEN AND SUPPORTERS.

Cyanogen has been described in a preceding part of this work.* At present we know only of one supporter with which it is capable of combining, without undergoing decomposition. This supporter is *chlorine*. The compound which it forms with this supporter has received the name of *chlorocyanic acid*. It will occupy our attention in the following section.

SECT. I.

OF CHLOROCYANIC ACID.

This acid was first recognised to exist by Berthollet, who gave it the name of *oxyprussic* acid. Its real nature was first ascertained by Gay-Lussac, in the year 1815.† He gave it the name of *chlorocyanic acid*.

Prepara-tion.

He prepared this acid by passing a current of chlorine gas through a solution of hydrocyanic acid in water till the liquid discoloured indigo dissolved in sulphuric acid. He then deprived it of the excess of chlorine which it contained by agi-

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* See vol. i. p. 235.

† Ann. de Chim. xcv. 136.

tating it with mercury. To separate chlorocyanic acid from this liquid, he took a glass cylinder, filled it two-thirds full of mercury; it was then filled to the brim with the hydrocyanic acid, saturated with chlorine, and inverted into a bason of mercury. This bason, with the cylinder in it, was put under the receiver of an air-pump, and the air of the receiver drawn out till the whole of the mercury, and even of the liquid, was displaced, and the cylinder filled with chlorocyanic acid in the state of an elastic vapour. On letting the air into the receiver, the vapour was condensed into a liquid, and the mercury again made its way into the cylinder. Chlorocyanic acid, thus obtained, possesses the following properties:

Properties. It is a colourless liquid, having a very strong and peculiar odour, so that a very small quantity of it irritates the pituitary membrane, and occasions tears. It reddens infusion of litmus, is not inflammable, and does not detonate when mixed with twice its weight of oxygen, or with hydrogen. Its specific gravity, in a state of vapour, determined by calculation, is 2·152. Its solution, in water, does not precipitate nitrate of silver, nor barytes water. The alkalies absorb it rapidly, but an excess of them is required to destroy its odour completely. If an acid be added to this solution, a strong effervescence takes place, carbonic acid is emitted, and if an excess of lime be mixed with the acid solution the odour of ammonia becomes perceptible. Thus the chlorocyanic acid is decomposed, and carbonic acid, muriatic acid, and ammonia, formed in its place. Composition. Gay-Lussac has shown that a volume of chlorocyanic acid, decomposed in this manner, produces

1 volume of muriatic acid
1 volume of carbonic acid
1 volume of ammoniacal gas.

Hence it follows that its elements are

2 volumes carbon
1 volume azote
1 volume chlorine.

Now, 2 volumes carbon + 1 volume azote, condensed into 1 volume, constitute *cyanogen*. And Gay-Lussac has shown, that when the chlorine of chlorocyanic acid is absorbed by antimony, it loses one half of its bulk. Hence it follows that chlorocyanic acid is a compound of 1 volume of cyanogen + 1 volume of chlorine, united together without any change of bulk. Of course its specific gravity must be the mean between the density of chlorine gas and cyanogen gas, and this is the specific gravity assigned above. Chlorocyanic acid, then, is a compound of 1 atom cyanogen + 1 atom chlorine; or it consists, by weight, of

Cyanogen	3·250	100
Chlorine	4·5	138·46

Chlorocyanic acid may be obtained mixed with carbonic acid (which gives it a gaseous state) when hydrocyanic acid, saturated with chlorine, is distilled.*

This acid has the property of throwing down iron from its solutions, of a green colour. The method of proceeding is to pour chlorocyanic acid into a solution of iron, to this mixture a little potash is added, and, finally, a little acid, which produces the precipitation of the iron. This property was recognized by Berthollet. It was it that induced him to consider chlorocyanic acid as a peculiar body.

The compounds which this acid forms with bases would receive the name of chlorocyanates. From the facts above stated, it appears that they possess but little permanence.

CHAP. II.

OF ACID COMPOUNDS OF CYANOGEN AND COMBUSTIBLES.

Cyanogen is capable of combining with hydrogen, sulphur, and iron, and of forming acids with each of these bodies. They have received the names of *hydrocyanic* acid, *sulphochyazic* acid, and *ferrochyazic* acid. These acids will occupy our attention in the three following sections.

SECT. I.

OF HYDROCYANIC OR PRUSSIC ACID.

History.

We are indebted to an accident for our knowledge of this important substance. About the year 1710 Diesbach, a preparer of colours in Berlin, wishing to prepare some lake by

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* Gay-Lussac; Ann. de Chim. xcv. 200.

precipitating a decoction of cochineal, alum, and green vitriol, with potash, borrowed some alkali for that purpose from Dippel. This chemist was the discoverer of a peculiar animal oil which goes by his name. He prepared it from blood; and the alkali with which he furnished Diesbach had been employed in the process. Instead of the red precipitate which he expected, a beautiful blue powder fell to the bottom. On mentioning the circumstance to Dippel, that chemist ascribed the formation of the powder to the action of his alkali on the alum and vitriol. It is not unlikely that he had calcined the potash together with a portion of blood. Be that as it may, he succeeded in discovering a method of procuring the blue powder at pleasure, and it was announced as a pigment in the Berlin Miscellanies for 1710. The preceding history, however, was only communicated to the public by Stahl 20 years after.*

This powder was called *Prussian blue;* and the method of procuring it remained concealed, because it had become a lucrative article of commerce, till Dr. Woodward published a process in the Philosophical Transactions for 1724, which he had procured, as he informs us, from one of his friends in Germany. This method was as follows: Detonate together four ounces of nitre and as much tartar, in order to procure an extemporaneous alkali; then add four ounces of dried bullock's blood; mix the ingredients well together, and put them into a crucible covered with a lid, in which there is a small hole; calcine with a moderate fire till the blood emits no more smoke or flame capable of blackening any white body exposed to it; increase the fire towards the end, so that the whole matter contained in the crucible shall be moderately but sensibly red. In this state throw it into four pounds of water, and boil it for half an hour. Decant off this water, and continue to pour on more till it come off insipid. Add all these liquids together, and boil them down to four pounds. Dissolve an ounce of sulphate of iron in half a pound of water, and eight ounces of alum in four pounds of boiling water: mix all the three solutions together while boiling hot. An effervescence takes place, and a powder is precipitated of a green colour. Separate this precipitate by filtration, and pour muriatic acid upon it till it becomes of a beautiful blue; then wash it with water and dry it.†

Preparation.

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* Stahl's Experiments, Observat. Animadvers. ccc. numero. Chim. et Phys. p. 281.

† Phil. Trans. xxxiii. 15.

Different explanations were given of the nature of this precipitate by different chemists. Mr. Brown immediately repeated the process of Woodward, ascertained that other animal substances, as *beef*, may be substituted for blood; that the alum is useful only to dilute the colour; and that the blue pigment is produced by the action of the alkali (altered by blood) on the iron of the vitriol. He ascertained, too, that prussian blue is insoluble in muriatic acid, and that the green colour is owing to a mixture of prussian blue and oxide of iron, and that the muriatic acid developes the blue colour by dissolving the oxide of iron.*

These facts were of considerable importance; but they threw no light upon the theory of the process. An explanation of this was first attempted by Geoffroy, who had ascertained that any animal body whatever might be substituted for blood. According to him, the blood communicates a portion of inflammable matter, or phlogiston, to the alkali, and this inflammable matter revives the iron of the vitriol and brings it to the metallic state. A greater quantity of blood, by increasing the inflammable matter, will enable the alkali to revive still more of the iron, and thus to strike a blue at once, instead of a green.† Though this explanation was approved of at the time by the best chemists, it was far from satisfactory.‡ Macquer soon after proceeded, by way of experiment, and added a new step to the facts ascertained by Brown.

Experiments of Macquer.

That celebrated chemist ascertained the following facts: 1. When an alkali is added to a solution of iron in any acid, the iron is precipitated of a yellow colour, and soluble in acids; but if iron be precipitated from an acid by an alkali prepared by calcination with blood (which has been called a *prussian alkali*), it is of a green colour. 2. Acids dissolve only a part of this precipitate, and leave behind an insoluble powder which is of an intense blue colour. The green precipitate therefore is composed of two different substances, one of which is prussian blue. 3. The other is the yellow oxide of iron; and the green colour is owing to the mixture of the blue and yellow substances. 4. When heat is applied to this prussian blue, its blue colour is destroyed, and it becomes exactly similar to common oxide of iron. It is composed therefore of iron and some other substance, which heat has the property of driving

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* Phil. Trans. 1724. xxxiii. 17.

† Mem. Par. 1725.

‡ Lewis's Neuman's Chem. p. 72

Book II. Division I.

off. 5. If it be boiled with a pure alkali, it loses its blue colour also, and at the same time the alkali acquires the property of precipitating of a blue colour solutions of iron in acids, or it has become precisely the same with the prussian alkali. 6. Prussian blue, therefore, is composed of iron and something which a pure alkali can separate from it, something which has a greater affinity for alkali than for iron. 7. By boiling a quantity of alkali with prussian blue, it may be completely saturated with this something, which may be called *colouring matter*, and then possesses the properties of a neutral salt. 8. No acid can separate this colouring matter from iron after it is once united with it. 9. When iron dissolved in an acid is mixed with an alkali saturated with the colouring matter, a double decomposition takes place; the acid unites with the alkali, and the colouring matter with the iron, and forms prussian blue. 10. The reason that, in the common method of preparing prussian blue, a quantity of yellow oxide is precipitated, is, that there is not a sufficient quantity of colouring matter (for the alkali is never saturated with it) to saturate all the iron displaced by the alkali; a part of it therefore is mixed with prussian blue. Muriatic acid dissolves this oxide, carries it off, and leaves the blue in a state of purity.—Such were the conclusions which Macquer drew from his experiments; experiments which not only discovered the composition of prussian blue, but threw a ray of light on the nature of affinities, which has contributed much towards the advancement of that important branch of chemistry.

The nature of the colouring matter, however, was still unknown. Macquer supposed it to be phlogiston. According to him, prussian blue is nothing else than iron supersaturated with phlogiston. This overdose protects the iron from acids, and prevents the magnet from acting on it. Heat drives off this dose, and leaves the prussian blue in the state of common iron.* From this theory, which differed but little from that of Geoffroy, the alkali saturated with the colouring matter of prussian blue received the name of *phlogisticated alkali.* Macquer having observed that it did not act on alkaline and earthy solutions, while it precipitated all the metals, proposed it as an excellent *test* for detecting the presence of these last bodies.

The subsequent experiments of chemists threw an air of suspicion on Macquer's theory. Baumé ascertained, that when

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* See Macquer's Dictionary, i. 177.

prussian blue is distilled, it always yields a portion of animal oil;* a product not very likely to appear if the powder contained nothing but phlogiston and iron. Deyeux and Parmentier, Bergman, Erxleben, Delius, and Scopoli, submitted prussian blue to distillation, and obtained a quantity of ammonia. Fontana ascertained that prussian blue detonated with nitre. Landriani obtained, by distillation, a little acid liquid and oil, and a great quantity of azotic gas and carburetted hydrogen gas. These facts were still more inconsistent, if possible, with Macquer's theory. Morveau advanced another in 1772; namely, that the phlogisticated alkali, besides phlogiston, contained also an acid which acted the principal part in the phenomena produced.† Sage affirmed that the colouring matter in phlogisticated alkali was phosphoric acid; but this opinion was refuted by Lavoisier.‡ Bergman also announced his suspicions that it was an acid, but an unknown one.§

Of Scheele.

Such was the knowledge of chemists respecting the nature of this colouring matter, when Scheele all at once removed the veil, and explained its properties and composition. This he performed in two dissertations on prussian blue, published in the Stockholm Transactions for 1782 and 1783.‖

He observed that the prussian alkali, after being exposed for some time to the air, lost the property of forming prussian blue; the colouring matter must therefore have left it.

Discovery of prussic acid.

He put a small quantity of it into a large glass globe, corked it up, and kept it some time; but no change was produced either in the air or the prussian alkali. Something must therefore displace the colouring matter when the alkali is exposed to the open air, which is not present in a glass vessel. Was it carbonic acid gas? To ascertain this, he put a quantity of prussian alkali into a glass globe filled with that gas, and in 24 hours the alkali was incapable of producing prussian blue. It is therefore carbonic acid gas which displaces the colouring matter. He repeated this experiment with this difference, that he hung in the globe a bit of paper which had been previously dipped into a solution of sulphate of iron, and on which he had let fall two drops of an alkaline lixivium in order to precipitate the iron. This paper was taken out in two hours, and became covered with a fine blue on adding a little muriatic

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* Baumé's Chemistry, ii. 601.

† Digressions Academiques, p. 249.

‡ Mem. Par. 1777, p. 77.

§ Notes on Scheffer, § 165.

‖ Scheele, ii. 111.

acid. Carbonic acid, then, has the property of separating the colouring matter from alkali without decomposing it.

He found also that other acids produce the same effect. Hence he concluded that the colouring matter might be obtained in a separate state. Accordingly he made a great many attempts to procure it in that state, and at last hit upon the following method, which succeeds perfectly.

Preparation.

Mix together 10 parts of prussian blue in powder, 5 parts of the red oxide of mercury, and 30 parts of water, and boil the mixture for some minutes in a glass vessel. The blue colour disappears, and the mixture becomes yellowish green. Pour it upon a filter; and after all the liquid part has passed, pour 10 parts of hot water through the filter to wash the residuum completely. The oxide of mercury decomposes prussian blue, separates its colouring matter, and forms with it a salt soluble in water. The liquid therefore which has passed through the filter contains the colouring matter combined with mercury. The other component parts of the prussian blue being insoluble, do not pass through the filter. Pour this mercurial liquid upon 2½ parts of clean iron filings, quite free from rust. Add at the same time 1 part of concentrated sulphuric acid, and shake the mixture. The iron filings are dissolved, and the mercury formerly held in solution is precipitated in the metallic state. The cause of this sudden change is obvious: The iron deoxidizes the mercury, and is at the same instant dissolved by the sulphuric acid, which has a stronger affinity for it than the colouring matter has. There remains in solution therefore only sulphate of iron and the colouring matter.

Now the colouring matter being volatile, which the sulphate of iron is not, it was easy to obtain it apart by distillation. Accordingly he distilled the mixture in a gentle heat: the colouring matter came over by the time that one-fourth of the liquor had passed into the receiver. It was mixed, however, with a small quantity of sulphuric acid; from which he separated it by distilling a second time over a quantity of carbonate of lime. The sulphuric acid combines with the lime and remains behind, which the colouring matter cannot do, because carbonic acid has a stronger affinity for lime than it has. Thus he obtained the colouring matter in a state of purity.

Composition.

It remained now to discover its component parts. He formed a very pure prussian blue, which he distilled, and increased the fire till the vessel became red. The small quantity of water which he had put into the receiver contained a portion of the blue colouring matter and of ammonia; and the air of the receiver consisted of azote, carbonic acid gas, and the colouring matter. He concluded from this and other experiments, that the colouring matter is a compound of ammonia and oil. But when he attempted to verify this theory by combining together ammonia and oil, he could not succeed in forming colouring matter. This obliged him to change his opinion; and at last he concluded that the colouring matter is a compound of ammonia and charcoal. He mixed together equal quantities of pounded charcoal and potash, put the mixture into a crucible, and kept it red-hot for a quarter of an hour; he then added a quantity of sal ammoniac in small pieces, which he pushed to the bottom of the melted mixture, kept it in the fire for two minutes till it had ceased to give out vapours of ammonia, and then threw it into a quantity of water. The solution possessed all the properties of the prussian alkali. Thus Mr. Scheele succeeded in forming the colouring matter.

This colouring matter was called *prussic acid* by Morveau in the first volume of the chemical part of the *Encyclopedie Methodique;* an appellation which soon became general in Great Britain and France.

These admirable experiments of Scheele were repeated and carried still farther by Berthollet in 1787; who applied to the explanation of the composition of the colouring matter the light which had resulted from his previous experiments on the component parts of ammonia. This illustrious chemist ascertained, in the first place, that the phlogisticated alkali is a triple salt, composed of prussic acid, the alkali, and oxide of iron; that it may be obtained in octahedral crystals; and that when mixed with sulphuric acid, and exposed to the light, it lets fall a precipitate of prussian blue. His next object was to ascertain the component parts of prussic acid. When chlorine is poured into prussic acid, obtained by Scheele's process, the acid becomes more odorous and more volatile, less capable of combining with alkalies, and precipitates iron from its solutions, not blue, but *green.* He conceived that in this case it had combined with oxygen, acquired new properties, and been converted into a new substance, which he called *oxy-prussic acid.*

From these experiments, and others similar to them, Berthollet concluded, that prussic acid does not contain ammonia ready formed; but that it is a triple compound of carbon, hydrogen, and azote, in proportions which he was not able to ascertain. This conclusion was verified by Mr. Clouet, who found, that when ammoniacal gas is made to pass through a red hot porcelain tube containing charcoal, a quantity of prussic acid is formed.[*] This experiment does not succeed unless a pretty strong heat be applied to the tube.[†]

In the year 1806, a most valuable paper on prussic acid and its compounds was published by M. Proust.[‡] Though he did not succeed in procuring the acid in a separate state, nor in ascertaining its constituents; with rigid accuracy he pointed out a great number of new and important facts which were of much utility, and which facilitated the subsequent investigations of Gay-Lussac. To this last illustrious chemist we are indebted for an easy process for obtaining prussic acid in a state of purity,[§] for an accurate description of its properties when thus obtained, and for a rigid determination of its composition and constitution.[||]

Experiments of Gay-Lussac.

How obtained pure.

Pure prussic or hydrocyanic acid may be obtained by the following process. Put into a small tubulated retort a mixture of prussiate of mercury[**] and muriatic acid. The quantity of acid should be less than would be requisite to decompose the prussiate of mercury completely. To the beak of the retort fit a glass tube about 2 feet in length and about $\frac{6}{10}$ths of an inch wide. Fill the first third of this tube with fragments of marble in order to retain any muriatic acid that might come over, (but care should be taken to prevent this as much as possible.) The remainder of the tube is to be filled with chloride of calcium to retain the water. To the extremity of this tube adapt a small receiver and surround it with ice, or still better, with a mixture of snow and salt. Apply a moderate heat to the retort. The hydrocyanic acid passes over and condenses at first on the marble. But it is easy, by applying a gentle heat, to drive it along the tube, and into the receiver.[††]

Properties.

I. Hydrocyanic acid, thus prepared, is a colourless liquid,

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[*] Ann. de Chim. xi. 30.

[†] Jour. de l'Ecole Polytechn. I. iii. 436.

[‡] Ann. de Chim. lx. 185.

[§] Ibid. lxxxiii. 215.

[||] Ibid. xcv. 136.

[**] This salt is obtained by boiling red oxide of mercury and prussian blue together, and evaporating the solution formed till it crystallizes. The crystals constitute *prussiate of mercury.*

[††] Ann. de Chim. xcv. p. 141.

having a strong smell similar to that of peach blossoms. Its taste is sharp, and at first appears cooling, but it soon excites a burning sensation in the mouth, and it is very asthenic, and indeed a virulent poison. At the temperature of 44½°, its specific gravity is 0·7058; at the temperature of 64½°; its specific gravity is 0·6969. It boils at the temperature of 79·7°, and congeals about the temperature of 5°. The cold which it produces when allowed to evaporate in the open air, even at the temperature of 68°, is sufficient to congeal it. The density of its vapour, compared to that of air, is by experiment 0·9476. By calculation its specific gravity ought to be 0·9368.

When the vapour of this acid is mixed with oxygen gas, and an electric spark passed through it, a detonation takes place. For complete combustion, 100 volumes of the vapour require 125 of oxygen. The products are 100 carbonic acid mixed with 50 azote. 100 of the oxygen went to the formation of carbonic acid. The remaining 25 of oxygen must have combined with hydrogen, and the quantity of hydrogen with which they combine must have been 50. Hence it follows that hydrocyanic acid must consist in bulk of

1 volume carbon,
½ volume azote,
½ volume hydrogen,

condensed into 1 volume. Hence we obtain its specific gravity by adding together the specific gravity of a volume of carbon, half the specific gravity of azotic gas, and half the specific gravity of hydrogen gas. These added together constitute 0·9368, which comes within about 1 per cent. of the specific gravity, as determined by experiment.

Composition.

When potassium is heated in vapour of prussic acid the whole vapour disappears, and is replaced by a quantity of hydrogen gas amounting to half its bulk. The potassium is converted into a grey spongy mass, which soon melts and acquires a yellow colour. When this matter is thrown into water it melts without effervescence, and the water contains a solution of common prussiate of potash. From this experiment it is obvious that the potassium absorbs all the hydrocyanic acid, except the hydrogen. But if the hydrogen be taken from this acid there remains only cyanogen. It is evident, then, that hydrocyanic acid is a compound of cyanogen and hydrogen. Nor can there be a doubt that it consists of equal volumes of these two bodies, united together without any condensation. Hence its specific gravity is the mean of the specific gravity of cyanogen and of hydrogen.

Sp. gravity of cyanogen ...	1·804
———— of hydrogen ...	0·0694
Mean	0·9367 = Sp. gr. of hydrocyanic acid.

Or in other words, hydrocyanic acid is a compound of 1 atom cyanogen + 1 atom hydrogen. So that its weight is 3·375; and its constituents by weight are,

Cyanogen	3·25	100
Hydrogen	0·125	3·846

Hydrocyanic acid cannot be preserved for any length of time without undergoing decomposition. Ammonia is formed, and a quantity of charry matter deposited. This charcoal must, of course, contain two thirds of the whole azote in the acid; so that it must be an azoturet of carbon.

Action of supporters.

II. Iodine may be volatilized in this acid vapour, without occasioning any change in it. Oxygen decomposes it with combustion when mixed with it, and fired by the electric spark. Chlorine displaces the hydrogen and forms chlorocyanic acid.

Action of combustibles.

III. Azote has no action on hydrocyanic acid. Neither is it acted on by hydrogen, carbon, boron, silicon, or phosphorus, at least, as far as is known. Sulphur decomposes it, displacing the hydrogen and converting it into sulphocyanic acid. Arsenic does not act upon it. The effect of tellurium has not been tried.

Potassium and sodium when heated in hydrocyanic acid absorb the cyanogen, and are converted into cyanodides, while the hydrogen is disengaged.

Barytes, potash, and soda, in like manner, absorb the cyanogen when assisted by heat, and become cyanodides, allowing the hydrogen to escape.

When hydrocyanic acid vapour is passed through red hot iron, it is completely decomposed. Carbon is deposited around the iron and partly combines with it, while equal volumes of azote and hydrogen are disengaged in the gaseous state. The same decomposition is produced by passing the vapour through red-hot platinum wire.

When vapour of hydrocyanic acid is passed through peroxide of copper heated to redness, the oxide is reduced, and the acid completely decomposed. Water is formed and a gas disengaged, which is a mixture of 2 volumes of carbonic acid, and 1 volume of azote. At the common temperature of the atmosphere, the oxide of copper converts the hydrogen of the acid into water, and cyanogen is evolved.

The peroxide of manganese absorbs completely the vapour of hydrocyanic acid in a few hours. Water is formed, but cyanogen is not evolved.

When red oxide of mercury is heated in hydrocyanic acid vapour, a violent action takes place, and so much heat is evolved as to destroy the compound formed. When the experiment is made without the application of heat, the vapour is obsorbed by the oxide. When the oxide thus saturated with vapour of hydrocyanic acid is heated, water is disengaged, and there remains the substance formerly known by the name of prussiate of mercury. Hence it is obvious that this compound is in reality a cyanide of mercury.*

Experiments of Scheele.

The following facts respecting the action of this acid on metallic oxides, determined by Scheele, deserve to be remembered.

Of all the metallic solutions tried by Scheele, pure prussic acid occasioned only a precipitate in three: namely,

1. Nitrate of silver precipitated white.
2. Nitrate of mercury precipitated black.
3. Carbonate of iron precipitated green becoming blue. It has no action on the oxides of

1. Platinum,
2. Iron,
3. Tin,
4. Lead,
5. Bismuth,
6. Antimony,
7. Manganese,
8. Arsenic,
9. Molybdenum.

10. Gold precipitated by the alkaline carbonates is rendered white by this acid.

11. It disengages carbonic acid from the oxide of silver, precipitated by the same alkalies; but the oxide remains white.

12. It dissolves red oxide of mercury, and forms with it a salt which may be obtained in crystals. This salt is cyanodide of mercury.

13. Oxide of copper precipitated by carbonate of potash effervesces in it, and acquires a slight orange-yellow colour.

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* The properties of hydrocyanic acid detailed in this section, were determined by Gay-Lussac. See Ann. de Chim. xcv. 144.

14. Oxide of iron precipitated from the sulphate of iron by carbonate of potash, effervesces in it, and becomes blue.

15. Oxide of cobalt precipitated by the same alkali, gives in it some marks of effervescence, and becomes yellowish brown.*

The salts which this acid forms with the different bases have been called *hydrocyanates.* They have little permanence, of course can scarcely be applied to any useful purpose, and indeed have scarcely been examined, since the time of Scheele, who first made them known.

SECT. II.

OF SULPHOCHYAZIC ACID.

Discovery. THIS acid was discovered by Mr. Porrett in 1808, and an account of it published by him soon after, under the name of *prussous acid*, because he considered it as differing from common prussic acid by containing less oxygen.† He afterwards ascertained that it contained sulphur, and published a detailed account of its properties, in the year 1814, under the name of *sulphuretted chyazic acid*, considering it as a compound of prussic acid and sulphur.‡

In the year 1817, M. Von Grotthus published an elaborate set of experiments on this acid,§ in which he gave a new method of preparing the acid, and endeavoured to show that it was a compound of hydrogen united to a peculiar base to which he gave the name of *anthrazothion*, and which he considered as a peculiar compound of sulphur, carbon, and azote. This was followed in 1818 by a set of experiments on the same acid by M. Vogel, of Munich,|| who rectified the process of Grotthus, and showed by very satisfactory arguments that the notion of the constitution of this acid given by Grotthus is inaccurate. In 1819 Mr. Porrett repeated his original experiments, and showed that the acid is a compound of 2 atoms of sulphur and 1 atom of hydrocyanic acid.**

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* Scheele, ii. 169.

† Published in the 27th volume of the Transactions of the Society for the Encouragement of Arts, Manufactures, and Commerce. From which it is copied into the Phil. Mag. xxxvi. 196.

‡ Phil. Trans. 1814, p. 527.

§ Annals of Philosophy, xiii. 39.

|| Ibid. p. 101.

** Ibid. p. 356.

Sulpho-chyazic acid may be obtained by the following process. Reduce any quantity of yellow prussiate of potash to powder, mix it with its own weight of flowers of sulphur, put the mixture into a flask and expose it to a heat sufficiently strong to melt the sulphur. Keep the mixture melted for several hours, then reduce it to powder, digest the powder in a sufficient quantity of water to take up every thing soluble. Pass the liquid through a filter, and drop into it a sufficient quantity of potash to precipitate any iron which it may hold in solution. The liquid thus prepared consists of a solution of sulpho-chyazate of potash in water. If we mix the solution with sulphuric acid and distil, pure sulpho-chyazic acid passes over into the receiver, together with a quantity of water. This is the process of Grotthus, as rectified by Vogel. I have repeated it several times and found it to answer very well.

Properties.

Sulpho-chyazic acid, thus obtained, is a transparent colourless liquid,[*] having an odour as strong, and a little resembling that of acetic acid. Its specific gravity, in the most concentrated form in which it was obtained by Mr. Porrett, was 1·022. At a boiling heat it dissolves a little sulphur. The greatest portion of this substance precipitates again when the liquid cools. The presence of sulphur in solution in it may be detected by nitrate of silver, which the acid, while pure, throws down white; but the colour of the precipitate is dark when the acid contains sulphur dissolved in it.

When this acid is distilled it leaves behind it a little sulphur and a portion of it is decomposed, so that it would be possible, by repeated distillations, to destroy the whole of it.

It boils at the temperature of 216½°, and at that temperature it is converted into vapour but not into gas. When the acid is thrown into a red hot platinum crucible, sulphur is disengaged, and at last burns with a blue flame. M. Vogel passed the acid through a red hot porcelain tube and obtained at the farther end of it sulphur, sulpho-chyazic acid undecomposed, and hydrocyanic acid, which was partly saturated with ammonia. If the tube be filled with iron turnings, sulphuret of iron is formed, and hydrocyanic acid and sulphuretted hydrogen disengaged. This acid, according to Vogel, crystallizes in the form of six-sided prisms at the temperature of 54·5°.[‡]

When this acid is mixed with a sufficient quantity of chlo-

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[*] Sometimes it acquires a pinkish hue.

[†] Vogel, Annals of Philosophy, xiii. p. 103.

rine, the whole of the sulphur is converted into sulphuric acid, and the hydrocyanic acid is disengaged. Iodine seems to produce nearly the same kind of change upon it.*

This acid forms a white insoluble compound with protoxide of copper. It is a protosulpho-chyazate of copper, which is composed, according to the analysis of Mr. Porrett, of†

Acid	45	7·394
Protoxide of copper	55	9
	100	

According to this analysis the equivalent number for sulphochyazic acid is 7·394.

To determine the composition of this acid Mr. Porrett exposed a mixture of 4·8 grains of protosulpho-chyazate of copper, and 12 grains peroxide of copper to the action of a spirit lamp.‡ 6·34 cubic inches of gas came over, consisting of

Carbonic acid	3·46 cubic inches, or	1·604 gr.
Azotic	1·73	
Sulphurous acid	1·15	0·779
	6·34	

The residue in the tube consisted of

Protoxide of copper	7·56 gr.
Copper	2·10
Sulphuret of copper	3·90
	13·56

Now 4·8 grains of the protosulpho-chyazate of copper are composed of

Acid	2·16 gr.
Base	2·64
	4·80

The whole oxygen contained in the peroxide of copper and protosulpho-chyazate was as follows:

In 12 grains peroxide	2·400 grains.
In 2·64 grains protoxide	0·293
Total	2·693

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* Vogel, Annals of Philosophy, xiii. p. 105.

† Annals of Philosophy, xiii. 359.

‡ Ibid. xiii. 360.

Of this 0·84 grain still remained united to the copper in the 7·56 grains of peroxide of copper. So that the whole of the oxygen consumed in the experiment amounted to 1·853 grain. Let us see how much of this exists in the carbonic acid and sulphurous acid produced.

1·604 grain of carbonic acid contains $\frac{8}{11}$ of 1·604 = 1·1938 grain of oxygen.

0·779 grain of sulphurous acid contains $\frac{1}{2}$ of 0·779 = 0·3896 grain. These two quantities make a total of 1·5834 grain. But the quantity consumed amounted to 1·853 grain. Hence, besides the oxygen in the carbonic acid and sulphurous acid, there was consumed 0·27 of a grain of oxygen. This oxygen must have gone to the formation of water. Now 0·27 grain of oxygen gas is very nearly 0·795 cubic inch. It must have combined with double its volume of hydrogen, or with 1·59 cubic inches.

Thus it appears that the carbon, azote, and hydrogen of sulphochyazic acid, supposing them in the gaseous state, would bear to each other the following proportions:

Carbon	3·46 volumes, or	2
Azote	1·73	1
Hydrogen ..	1·59	0·919

Thus the proportions are very nearly the same as in hydrocyanic acid. There is a small deficiency in the hydrogen. But if we attend to the method employed to ascertain it we shall not be surprised at this deficiency, which scarcely exceeds 8 per cent.

To know the constitution of the acid it remains only to determine the quantity of sulphur present. Sulphur in the state of vapour has the same specific gravity as oxygen gas, and sulphurous acid contains its own volume of sulphur in the state of vapour. From these data it is easy to determine the volume of sulphur in 2·16 grains of sulphochyazic acid.

For the sulphur in 3·9 grains of sulphuret of copper = 0·78 grain = 2·3017 cubic inches of sulphur vapour. This added to 1·15 (the volume of sulphurous acid) makes a total of 3·4517 cubic inches. Thus we see that the volume of sulphur (when in the state of vapour) is the same as that of the carbon in sulphochyazic acid. It appears, therefore, that the constituents of the acid are

2 volumes sulphur,
2 volumes carbon,

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1 volume azote,
1 volume hydrogen.

By substituting atoms for volumes we obtain the true weight and constitution of the acid. It is composed of

2 atoms sulphur	= 4
2 atoms carbon	= 1·5
1 atom azote	= 1·175
1 atom hydrogen	= 0·125
	7·375

Sulpho-chyazates.

I shall now state the facts that have been ascertained respecting the compounds of this acid with salifiable bases—compounds to which the name of *sulphochyazates* may be given. For every thing known respecting these salts we are indebted to Mr. Porrett.*

1. *Sulphochyazate of ammonia.* This is a soluble salt which does not crystallize, but is soluble in alcohol.

2. *Sulphochyazate of potash.* A deliquescent salt, soluble in alcohol.

3. *Sulphochyazate of soda.* A deliquescent salt, soluble in alcohol. It crystallizes in rhomboids.

4. *Sulphochyazate of lime.* A deliquescent salt, soluble in alcohol, from which it may be obtained in a mass of needleform crystals.

5. *Sulphochyazate of barytes.* A deliquescent salt, crystallizing in long slender prisms of a brilliant white colour. This salt, according to the analysis of Mr. Porrett, is composed of

Sulphochyazic acid	2·95	100	4·150
Barytes	6·93	234·915	9·750
	9·88		

6. *Sulphochyazate of strontian.* A deliquescent salt, crystallizing in long slender prisms in groups, radiating like zeolite.

7. *Sulphochyazate of magnesia.* A deliquescent, incrystallizable salt. When dried it has a micaceous appearance.

8. *Sulphochyazate of alumina.* It crystallizes in octahedrons, and does not deliquesce.

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* Phil. Trans. 1814, p. 552.

9. *Protosulphochyazate of iron.* A colourless salt, very soluble in water.

10. *Persulphochyazate of iron.* A salt of a beautiful crimson colour, deliquescent, and only obtainable in a solid form by exposure to an atmosphere artificially dried.

11. *Sulphochyazates of nickel, cobalt, manganese, uranium, zinc, bismuth.* Very soluble.

12. *Sulphochyazate of lead.* A soluble salt. Crystals obtuse rhombs. In a moist atmosphere slowly deliquesces.

13. *Sulphochyazate of tin.* Very soluble.

14. *Protosulphochyazate of copper.* A white powder, insoluble in water and in most acids, decomposable by alkalies, or by distillation with sal ammoniac; also by mixture with pernitrate of iron. When mixed with five times its weight of chlorate of potash it explodes by heat, friction, the contact of sulphuric acid, or the electric spark. This salt, according to the analysis of Mr. Porrett, is composed of

Sulphochyazic acid ..	45·00	7·394
Protoxide of copper ..	55·00	9·
	100·00	

15. *Persulphochyazate of copper.* This salt may be formed by mixing together sulphochyazate of soda and persulphate of copper. It is then in the state of a bright pea-green liquid, to which if any deoxidizing substance be added as sulphurous acid, an alkaline sulphite or the salts of protoxide of tin or of iron, protosulphochyazate of copper is immediately produced and precipitates in the state of a white powder.

16. *Protosulphochyazate of mercury.* A white insoluble powder.

17. *Sulphochyazate of silver.* A white insoluble salt.

18. *Sulphochyazate of palladium.* Very soluble.

19. *Sulphochyazate of potash united to cyanide of mercury.* Mr. Porrett informs us that these two substances are capable of uniting together and forming a compound salt, which has a brilliant silvery lustre, is but little soluble in cold water, but very soluble in hot, from which it may be obtained in crystals by cooling.

SECT. III.

OF FERROCHYAZIC ACID.

Book II. Division I.

Discovery.

When hydrocyanic acid is combined with the salifiable bases it forms salts which cannot be exposed to the atmosphere without undergoing decomposition, and whose acid is displaced by every other acid with which we are acquainted. But when salts are formed by boiling the salifiable bases together with prussian blue, we obtain compounds of a very different nature. They are not only permanent in the atmosphere, but their acid adheres with so much obstinacy that it is not easily displaced by any other acid however powerful. It was long ago perceived that the salts formed by this last process contained as a constituent a considerable proportion of oxide of iron. Yet this iron cannot be made manifest by the usual reagents. It is not precipitated by phosphoric acid, or by alkalies, as happens in all other cases when iron is held in solution by acids. The nature of these salts therefore was somewhat enigmatical, as they presented phenomena inconsistent with what we behold in other cases. The difficulty has been at last removed by Mr. Porrett, who endeavoured to show that these salts contain an acid hitherto unknown, composed of protoxide of iron and hydrocyanic acid, and to which he has given the name of *ferruretted chyazic acid.* This acid may be obtained by the following process:

Preparation.

Dissolve in cold water the salt hitherto called *triple prussiate of barytes;* and for every ten grains of the salt so dissolved add 2.53 grains of real sulphuric acid, agitate the mixture, and set it aside for some time. The whole of the barytes and sulphuric acid precipitate in combination, and leave the ferrochyazic acid dissolved in the water.* This acid possesses the following characters.

Properties.

It has a pale lemon-yellow colour, and is destitute of smell. It is decomposed by a gentle heat or by exposure to a strong light. Hydrocyanic acid is then formed, and white triple prussiate of iron, which by exposure to the air quickly becomes blue. When combined with the salifiable bases it forms the salts called triple prussiates. It displaces acetic acid from its combinations without the assistance of heat, and forms

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* Phil. Trans. 1814, p. 580.

triple prussiates with the bases previously united to that acid. It expels all acids from soluble combinations when it is capable of forming insoluble salts with the bases to which they were united.*

That ferrochyazic acid is a peculiar acid, is farther proved by what happens when a solution of triple prussiate of soda is exposed to the action of the galvanic battery. Its acid (including the iron) was deposited at the positive pole, where, in consequence probably of the decomposition of water, hydrocyanic acid was volatilized, and blue prussiate of iron deposited.

Mr. Porrett has pointed out an ingenious process for obtaining this acid in the state of crystals. It is as follows: Dissolve 58 grains of crystallized tartaric acid in alcohol and 50 grains of ferrochyazate of potash in as little warm water as possible. Mix the two liquids. Bitartrate of potash is precipitated and the ferrochyazic acid remains in solution. By spontaneous crystallization it separates in small yellow coloured cubes. I have repeated this experiment with success. The crystals of ferrochyazic acid are soon destroyed when left exposed to the action of light. They become coated with prussian blue and lose their regular shape. The same change took place even when the acid was kept in a press excluded from the light by a wooden door, which however was very often opened.

The analysis of this acid is attended with considerable difficulty, owing chiefly to the ease with which the iron which it contains is volatilized. Mr. Porrett concluded, from a set of experiments, of which an account may be seen in the Philosophical Transactions for 1816,† that it is a compound of 4 atoms of hydrocyanic acid and 1 atom of black oxide of iron. In the year 1818 I published a set of experiments on the ferrochyazate of potash, and drew as a conclusion from them, that it was probably a compound of 1 atom of hydrocyanic acid and half an atom of iron, acknowledging at the same time that this hypothesis did not agree exactly with the products which I obtained, the quantity of carbon and of hydrogen being too great for a single atom of hydrocyanic acid.‡ Mr. Porrett soon after wrote a new paper on the subject, in which he endeavoured to show that the acid was a

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* Porrett, Phil. Trans. 1814, p. 530. † P. 220.

‡ Annals of Philosophy, xii. 102.

compound of 2 atoms of hydrocyanic acid + an atom of azote, + an atom of iron.* But this statement cannot be reconciled to the quantity of iron which is detected in the acid by analysis, and which amounts only to half an atom.

In October 1819, Mr. Porrett published a new set of experiments on this acid,† in which he admits that the proportion of iron, which I separated from the acid, was not below the truth, and of course concedes that the iron in this acid amounts only to half an atom. He obtained from the analysis of 1 grain of the ferrochyazate of potash, by means of peroxide of copper, the following substances:‡

		Grains.
Carbonic acid	1·79 cubic inches	= 0·226 carbon.
Azotic gas	.. 0·45	= 0·133 azote.
Hydrogen	.. 0·377	= 0·008 hydrogen.
		0·367

In this analysis there is an excess of 0·06 grains. I have repeated the analysis of this acid at least 20 times, in order, if possible, to verify Mr. Porrett's results. But I have not been able to obtain conclusions in the least similar to those which he has stated. I am under the necessity therefore of differing in opinion from this ingenious chemist, and of concluding, in conformity with my original paper,§ that ferrochyazic acid is a compound of 1 atom of hydrocyanic acid, and half an atom of iron. I even entertain suspicions that the opinion which I advanced in the last edition of this work; namely, that ferrochyazic acid is a compound of cyanogen and iron will be ultimately verified. I have, indeed, always obtained such a quantity of water in my experiments as indicates the presence of hydrogen in the acid. But Dr. Prout, who has repeated the analysis with a more perfect apparatus than mine, has not obtained a greater proportion of water than may be supposed to exist in the salt in the state of water of crystallization. Farther researches are therefore necessary before this point can be considered as ultimately decided. 5 grains of the crystals of ferrochyazate of potash, when heated with peroxide of copper, give out 8 cubic inches of gas. Of this 4·6 cubic inches are absorbed by potash, and therefore are carbonic acid gas. The remaining 3·4 cubic

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* Annals of Philosophy, xii. 214.

† Ibid. xiv. 295.

‡ Ibid. 296.

§ Ibid. xii. 102.

inches are azotic gas. But the potash in the salt remains in the state of a carbonate. If we add this carbonic acid to the 4·6 cubic inches evolved, we shall have almost exactly 6·8 cubic inches, which is just double the volume of the azotic gas disengaged. It follows, therefore, that in ferrochyazic acid the volume of carbon is just twice that of the azote. Hence the acid contains 2 atoms of carbon (and not 4 as Mr. Porrett affirms) for every atom of azote. According to an experiment with which Dr. Prout furnished me, 5 grains of ferrochyazate of potash, when heated with peroxide of copper, lose about 4 grains of weight (if we include the carbonic acid still retained by the potash in the loss). Now this is scarcely equivalent to the weight of the carbonic acid and of the azotic gas evolved. So that, according to this experiment, the acid does not appear to contain any hydrogen. But as I myself, in all my experiments, always obtained water, I consider it as proved, that the acid is composed as follows:

2 atoms carbon	=	1·5
1 atom azote	=	1·75
1 atom hydrogen	=	1·25
½ atom iron	=	1·75
		5·125

But as the equivalent number 5·125 cannot be reconciled to the composition of the salt, I see no other alternative than to suppose that the iron in reality amounts to a whole atom; although I have only been able to obtain half an atom. On that supposition ferrochyazic acid must be composed as follows:

2 atoms carbon	1·5
1 atom azote	1·75
1 atom hydrogen	0·125
1 atom iron	3·5
	6·875

This would make the weight of the equivalent number for the acid 6·875. I am disposed to suspect that it will ultimately turn out to be 6·75, which would be the weight of an atom of cyanogen united to an atom of iron. But the whole of this investigation is still very obscure. I have not been able to throw any additional light on the subject since the publication of my paper in 1818.

Let us now proceed to describe the compounds which ferrochyazic acid makes with the salifiable bases. These salts have (many of them) a yellow colour, and were formerly distinguished by the name of *triple prussiates*. We must of course give them the name of *ferrochyazates*.

1. *Ferrochyazate of ammonia.* This salt was discovered by Macquer. It forms hexangular crystals of a light lemon-yellow colour, is very soluble in water, and deliquesces when exposed to the air.

2. *Ferrochyazate of potash.* This salt was first formed by Macquer, and proposed by him as a test to determine the presence of metallic bodies in solution, and to ascertain the kind of metal, and has in consequence acquired great celebrity and attracted a great deal of attention. It was called successively *phlogisticated alkali, prussian alkali, triple prussiate of potash;* and was usually prepared by boiling prussian blue in a potash ley till the alkali was completely saturated. The liquid was then filtered and evaporated till the salt crystallized. It is now manufactured in the large way by Messrs. Macintosh and Co. Glasgow, from whom it may be procured in most magnificent crystals, and in the state of greatest purity.

The colour of the salt is a fine topaz yellow. It is transparent, and appears green by transmitted light. The figure of the crystals is a square plate with bevelled edges. We may consider it as an octahedron composed of two four-sided pyramids applied base to base, and the apexes of each pyramid truncated very deep by a plane parallel to the bases of the pyramids. The bevelled edges of the table, or the two contiguous faces of the truncated pyramids, are inclined to each other at an angle of about 135°. The specific gravity of these crystals is 1·833. They are sectile, and may be easily split into plates parallel to the bases of the pyramids. These plates admit of being bent without breaking.

Its taste is saline and cooling, and by no means disagreeable. Its solubility in distilled water at different temperatures is as follows:

A 54°, 100 parts of water dissolve	27·8 of the salt.
100	65·8
150	87·6
200	90·6

It is insoluble in alcohol and in sulphuric ether. When exposed to heat it gives out moisture and assumes a white colour: but it does not melt, nor do the crystals lose their shape unless the heat approaches to redness. Even a long exposure to a red heat does not destroy the acid, though it renders the salt strongly alkaline.

Ferrochyazate of soda,

3. *Ferrochyazate of soda.* This salt may be prepared by a process similar to that described for preparing the preceding salt. For the first detailed description of it we are indebted to Dr. John.

Its colour is yellow. It crystallizes in four-sided prisms terminated at both extremities by dihedral summits. They are transparent, and have a bitter taste; when left in a warm place they fall down in the state of a white powder, and lose 37½ per cent. of their weight. At the temperature of 55° they require 4½ times their weight of water to dissolve them; but they are much more soluble in boiling water, a portion of the salt crystallizing as the solution cools. The specific gravity of the crystals is 1·458. They are soluble in alcohol.[*]

Of lime.

4. *Ferrochyazate of lime.* This salt was perhaps first mentioned by Mr. Hagen;[†] but we are indebted to Morveau for the first accurate account of its properties and preparation.[‡]

Upon two parts of prussian blue of commerce, previously well washed with a sufficient quantity of boiling water, to separate all the foreign salts, about 56 parts of lime-water are to be poured, and the mixture must be boiled for a short time till the lime is saturated with the ferrochyazic acid, which is known by its no longer altering paper stained with turmeric; it is then to be filtered.

This liquid, which contains the ferrochyazate of lime in solution, has a greenish-yellow colour; its specific gravity is 1·005; and it has an unpleasant bitterish taste. When evaporated to dryness, it yields small crystalline grains, soluble without alteration in water. It is insoluble in alcohol.

Of barytes.

5. *Ferrochyazate of barytes.* For the first accurate description of this salt we are indebted to Dr. Henry. It may be formed by adding prussian blue to hot barytes water till it ceases to be discoloured. The solution, when filtered and gently evaporated, yields crystals of ferrochyazate of barytes.

These crystals have the figure of rhomboidal prisms; they have a yellow colour, and are soluble in 1920 parts of cold

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[*] Gehlen's Jour. 2d Series, iii. 171.

[†] Crell's Annals, 1784, i. 291.

[‡] Encyc. Method. Chim. i. 242.

water, and in about 100 parts of boiling water. In a red heat they are decomposed, the acid being destroyed. They are soluble in nitric and muriatic acids; sulphuric acid occasions a precipitate of sulphate of barytes.* Mr. Porrett† has analyzed this salt. According to his experiments it is composed of

Ferrocyanic acid....	34·31
Barytes............	49·10
Water............	16·59
	100·00

Doubtless its true composition is

1 atom ferrochyazic acid =	6·75	36
1 atom barytes........ =	9·75	52
2 atoms water .... =	2·25	12
	18·75	100

Of strontian.

6. *Ferrochyazate of strontian.* This salt was also first examined by Dr. Henry. It may be formed by the same process as the last species; but the solution does not crystallize nearly so readily. When evaporated to dryness it does not deliquesce, and is again soluble in less than four parts of cold water.‡

7. *Ferrochyazate of magnesia.* This salt was examined by Hagen in 1782; but since that time scarcely any attention has been paid to it.

8. *The ferrochyazates* of *yttria, glucina, alumina,* and *zirconia,* have not been hitherto examined.

Of iron.

9. *Protoferrochyazate of iron.* This salt was discovered by Proust.§ It is a white powder which is precipitated when ferrochyazate of potash is dropped into protosulphate of iron, freed by boiling from atmospherical air. By exposure to the atmosphere it is speedily converted into prussian blue.

10. *Perferrochyazate of iron.* This is the blue pigment which has been so long known by the name of prussian blue. It is a deep blue powder, insoluble in water, and scarcely soluble in acids. It is not affected by exposure to the air. Heat decomposes it by destroying the acid, and the oxide of iron remains behind. The prussian blue of commerce, be-

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* Nicholson's Jour. iii. 170.

† Phil. Trans. 1814, p. 535.

‡ Nicholson's Journal, iii. 171.

§ Nicholson's 4to. Jour. i. 453.

sides other impurities, contains mixed with it a great quantity of alumina. When boiled with alkaline lye, in the state of a very fine powder, the whole of the acid may be removed. And if the residual powder be sufficiently washed with water, it contains nothing but peroxide of iron, supposing the prussian blue to have been free from all impurity. This salt, according to the experiments of Mr. Porrett,* is composed of

Ferrochyazic acid	53·38	100	6·750
Peroxide of iron	34·23	64·12	4·328
Water	12·39		
	100·00		

I analyzed it by means of potash and found its constituents to be

Ferrochyazic acid	51·0
Peroxide of iron	37·8
Water	11·2
	100·00

It is obvious that the specimen which I analyzed was a compound of 1 atom acid + 1 atom peroxide + 1 atom water. But there was a slight excess of water, probably because the powder had not been sufficiently dried. To dry it is difficult, because it catches fire at a temperature between 400° and 500°, and burns with a good deal of vividness; but without flame, and exhales at the same time a good deal of ammonia. Supposing the salt properly dried, its constituents would undoubtedly be

1 atom acid	= 6·75	52·42
1 atom peroxide	= 5·00	38·83
1 atom water	= 1·125	8·75
	12·875	100·00

When this salt is heated to redness it gives out hydrocyanic acid, ammonia, and a peculiar combustible gas composed of 3 volumes carbon and 4 volumes hydrogen condensed into one-third of their bulk. Its specific gravity is 0·6743. 100 volumes of it for complete combustion require 233·8 volumes of oxygen, and form 143⅓ volumes of carbonic acid gas. Prussiate of iron can scarcely be completely decomposed by exposure to a red heat. The residue takes fire of its own

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* Phil. Trans. 1814, p. 536.

accord when exposed to the air, and gives out at the same time a quantity of ammonia.

Colour of metallic precipitates.

11. As the remaining ferrochyazates have not been hitherto examined with much attention by chemists, I shall satisfy myself with giving the following table of the colours of the various precipitates formed by pouring ferrochyazate of potash into solutions of the different metallic bodies.

Metals.	Colour of Precipitates.
Iron	Blue.
Nickel	Milk white.
Cobalt	Grass green.
Manganese	Peach blossom.
Cerium	White.
Uranium	Brownish red like blood.
Zinc	White.
Bismuth	White.
Lead	White.
Tin	White.
Protoxide of copper	White.
Peroxide of copper	Reddish brown.
Mercury	O.
Silver	White, becoming blue.
Gold	O.
Platinum	O.
Palladium	Olive.
Rhodium	O.
Iridium	Becomes colourless.
Antimony	O.
Chromium	Green.
Molybdenum	O.
Tungsten	O.
Columbium	Olive.
Titanium	Yellowish brown.*

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* *Grass green* if any iron be present. See Vauquelin, Jour. de Phys. lxvi. 345.

SUBDIVISION VI.

OF COMPOUND COMBUSTIBLES.

Subdiv. VI.

Though the substances belonging to this division appear, at first sight, very different from those belonging to the five preceding subdivisions, I believe that the difference is more apparent than real, and that all of them might, without difficulty, be arranged under three divisions similar to the divisions under which the compounds of oxygen and combustibles have been reduced. For many of the compound combustibles possess properties analogous to acids; some of them possess properties analogous to salifiable bases; and those few which are neither referable to acids or bases might be placed under the head of oxides. But I do not think the science sufficiently far advanced to derive advantage from such an arrangement. I shall not, therefore, attempt it at present. Neither shall I introduce into this part of the work the whole of the compound combustibles, which comprehend the greater number of animal and vegetable substances. The investigation of vegetable and animal bodies is too incomplete; their properties are too imperfectly known to allow us to introduce them into the first principles of the science; and the utility of the greater number of them as chemical instruments is too inconsiderable to warrant any such introduction, even if their properties were completely investigated. For these reasons, it will be proper to treat in this chapter of those compound combustibles only which are employed in chemistry as instruments of investigation, reserving the remainder for the second part of this work. These may be reduced under five classes; namely,

1. Alcohol
2. Ether
3. Volatile oils
4. Fixed oils
5. Bitumens

The properties of these bodies form the subject of the following sections.

CHAP. I.

OF ALCOHOL.

Book II. Division I. History.

The liquid called *alcohol*, or *spirit of wine*, is obtained by distilling *wine*, *beer*, and similar fermented liquors. These liquors appear to have been known in the earliest ages. The Scripture informs us that Noah planted a vineyard and drank wine; and the heathen writers are unanimous in ascribing the invention of this liquor to their earliest kings and heroes. Beer, too, seems to have been discovered at a very remote period. It was in common use in Egypt during the time of Herodotus.* Tacitus informs us that it was the drink of the Germans.† Whether the ancients had any method of procuring ardent spirits from these or any other liquors does not appear. The Greeks and Romans seem to have been ignorant of ardent spirits altogether, at least we can discover no traces of any such liquor in their writings: but among the northern nations of Europe, intoxicating liquors were in use from the earliest ages. Whether these liquors resembled the beer of the Germans we do not know.

At what period these liquors were first subjected to distillation is unknown; though it can scarcely have preceded the time of the alchymists. The process is simple. Nothing more is absolutely necessary than to boil them in a still. The first portion of what comes over is *ardent spirits*. It is certain, at least, that the method of procuring ardent spirits by distillation was known in the dark ages; and it is more than probable that it was practised in the north of Europe much earlier. They are mentioned expressly by Thaddæus, Villanovanus, and Lully.‡

It is by the distillation of fermented liquors that ardent spirits are obtained; and they receive various names according to the nature of the substance employed. Thus *brandy* is procured from wine, *rum* from the fermented juice of the sugar-cane, *whisky* and *gin* from the fermented infusion of malt or grain. Now ardent spirits, whatever be their name, consist almost entirely of three ingredients; namely, *water, pure spirit* or alcohol, and a little *oil* or *resin*, to which they owe their flavour and colour.

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* Lib. ii. n. 77.

† De Morib. Germ. ch. xxiii.

‡ Bergman, iv. art. ii. 4.

Rectified spirits.

1. When these spirituous liquors are re-distilled, the first portion that comes over is a fine light transparent liquid, known in commerce by the name of *rectified spirits*, and commonly sold under the denomination of alcohol or spirit of wine. It is not, however, as strong as possible, still containing a considerable portion of water.

Preparation of alcohol.

The method usually practised to get rid of this water is to mix the spirits with a quantity of very dry and warm *salt of tartar*.* This salt has a strong attraction for water, and the greatest part of it is insoluble in alcohol. It accordingly combines with the water of the spirit; and the solution thus formed sinks to the bottom of the vessel, and the alcohol, which is lighter, swims over it, and may easily be decanted off; or, what is perhaps better, the solution of potash may be drawn off from below it by means of a stopcock placed at the bottom of the vessel.† The alcohol, thus obtained, contains a little pure potash dissolved, which may be separated by distilling it in a water bath with a very small heat. The spirit passes over, and leaves the potash behind. It is proper not to distil to dryness. This process is first mentioned by Lully. The liquid procured by means of it has been usually distinguished by the name of *alcohol*.

Alcohol is said to have been discovered, or at least first accurately described, by Arnold de Villa Nova, who was born about the end of the thirteenth century. This chemist, who was professor of medicine at Montpelier, first formed tinctures, and introduced them into medicine.‡

Strength of common alcohol.

The specific gravity of spirits, as highly rectified as possible by repeated distillations, seems to be about 0·820, at the temperature of 60°; but the alcohol of commerce, which is nothing else than rectified spirits, is seldom under ·8371. By means of salt of tartar Muschenbroeck brought it as low as ·815; but, in general, the alcohol concentrated by that process is not under ·821, owing to the weakness of the spirits employed. Even at the specific gravity ·815 the alcohol is by no means pure, still containing a considerable portion of water.

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* Impure potash not fully saturated with carbonic acid.

† See this process described by Hoffman as new, in his Observationes Phys.-Chim. Select. p. 36, published in 1722.

‡ He is said also to have been the first who obtained the oil of turpentine. He procured it by distilling turpentine, and employed it as a solvent of resins.

Dr. Black, by repeated distillations off muriate of lime, obtained it as low as ·800; but it was Lowitz of Petersburgh who first hit upon a method of obtaining alcohol in a state of absolute purity, or at least very nearly so. His process was published in 1796;* and the same year Richter made known another, by which the same purification was accomplished with still greater facility.†

Method of procuring pure alcohol.

The process of Lowitz is as follows: take a quantity of fixed alkali‡ perfectly dry, and still warm, and nearly fill with it a retort. Upon this pour such a quantity of alcohol (previously brought to ·821 by means of salt of tartar) as can be absorbed by the alkali completely, so that the whole shall have the appearance of a solid mass without any alcohol swimming above. In general, the portion ought to be two parts alkali and one part alcohol. Allow this mixture to remain for 24 hours, and then distil by a heat so moderate, that about two seconds elapse between the falling of the drops of alcohol from the beak of the receiver. When this interval increases, the receiver must be changed; for it is a sign that all the strong alcohol has come over. What comes over next is weaker. By this process Lowitz obtained alcohol of the specific gravity 0·791 at the temperature of 68°.

When Richter repeated the experiment of Lowitz, he reduced the alcohol to the specific gravity 0·792 at the temperature of 68°, but could not bring it any lower. He found, upon trial, that the following method, which is much more expeditious, answered equally well with that of Lowitz: he exposed a quantity of the salt called muriate of lime to a red heat, reduced it to powder, and introduced it while yet warm into a retort, and poured over it at intervals a quantity of alcohol, of 0·821, nearly equal to it in weight. A violent heat was produced. The retort was put upon a sand-bath, a receiver adjusted, and the liquid made to boil. The salt was dissolved, and formed with the alcohol a thick solution. The portion that had passed over into the receiver was now poured back, and the whole distilled by a gentle boiling nearly to dryness. The alcohol that came over was of the specific gravity 0·792 at the temperature of 68°.

Properties.

2. Alcohol obtained by these processes is a transparent li-

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* Crell's Annals, 1796, i. 195.

† Ibid. ii. 211.

‡ I presume in the state of carbonate.

quor, colourless as water, of a pleasant smell, and a strong penetrating agreeable taste. When swallowed it produces intoxication. Its properties differ somewhat according to its strength. When procured by Lowitz's or Richter's process, we may distinguish it by the name of *pure alcohol*, or *absolute alcohol*, as no method known can deprive it of any more water. When the specific gravity is higher, the alcohol is contaminated with water, and the proportion of that liquid present increases with the specific gravity. Chemists, in general, have employed this impure alcohol, or this mixture of alcohol and water, in their experiments; and as they have too often neglected to point out the specific gravity of the spirit used, we are still in some measure ignorant of the properties of this important liquid.*

3. Alcohol is perfectly limpid and remarkably fluid, and it may be exposed to a lower temperature than any other known substance without losing its fluidity. Mr. Walker of Oxford reduced an alcohol thermometer to the temperature of − 91° without producing any change in it. But Mr. Hutton of Edinburgh announced in 1813, that he had been able to freeze it by exposing it to a cold of − 110°. The alcohol employed by him was of the specific gravity 0.798 at the temperature of 60°. He says that the alcohol divided into three layers. The uppermost was yellow, the undermost was alcohol. What the middle one was he does not say.† But as Mr. Hutton has thought proper to conceal the method which he employed, and as no one else has been able to produce so great a degree of cold, the freezing of alcohol must still be considered as doubtful.

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* Fahrenheit was one of the first who ascertained some of the remarkable properties of alcohol with exactness. His alcohol was of the specific gravity ·825 at the temperature of 48°. See Phil. Trans. 1724, vol. xxxiii. p. 114. Fourcroy informs us that the specific gravity of the most highly rectified alcohol is 0·8293, without specifying the temperature. The extremity of Baumé's hydrometer for spirits, (according to Nicholson's table, Quarto Jour. i. 39), answers to the specific gravity ·817, temp. 55°. This may be considered as beyond the strength of the alcohol used. In Germany, before Lowitz's experiments, the strongest alcohol seems seldom to have exceeded 0·821 at 68°; and in this country it is commonly considerably weaker. The highest point of Clark's hydrometer corresponds with alcohol of about ·834 at 30°. Dr. Lewis states the purest alcohol of the specific gravity 0·820.—Neuman's Chem.

† Annals of Philosophy, i. 221.

It is a very volatile liquid. Fahrenheit found that alcohol of the specific gravity of about ·820, at the temperature of 60°, boiled when heated to 176°.* When of the specific gravity ·800 it boils at 173½°. At this heat it assumes the form of an elastic fluid, capable of resisting the pressure of the atmosphere, but which condenses again into alcohol when that temperature is reduced. In a vacuum it boils at 56°, and exhibits the same phenomena: so that were it not for the pressure of the atmosphere, alcohol would always exist in the form of an elastic fluid, as transparent and invisible as common air. This subject was first examined with attention by Mr. Lavoisier.† The fact, however, had been known long before. The specific gravity of the vapour of alcohol according to the experiments of Gay-Lussac is 1·6133.‡ I believe the true specific gravity to be 1·6000.

Combination with water.

4. Alcohol has a strong affinity for water, and is miscible with it in every proportion. The specific gravity varies according to the proportion of the two liquids combined; but, as happens in almost all combinations, the specific gravity is always greater than the mean of the two liquids; consequently there is a mutual penetration: and as this penetration or condensation varies also with the proportions, it is evident that the specific gravity of different mixtures of alcohol and water can only be ascertained by experiment. As the spirituous liquors of commerce are merely mixtures of alcohol and water in different proportions, and as their strength can only be ascertained with precision by means of their specific gravity, it becomes a point of very great importance to determine with precision the proportion of alcohol contained in a spirit of a given specific gravity: and as the specific gravity varies with the temperature it is necessary to make an allowance for that likewise.

The importance of knowing with precision the proportion of alcohol contained in spirits of every specific gravity, has induced many different persons to make experiments in order to ascertain this point with exactness; but as they set out from alcohol of very different strengths, it is not easy to compare their results with each other. We have seen that the pure alcohol, by Lowitz' process, is of the specific gravity ·791

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* Phil. Trans. 1724, vol. xxxiii. p. 1.

† Jour. de Phys. 1785.

‡ Ann. de Chim. et Phys. i. 218.

at the temperature of 68°. That chemist mixed various proportions of this alcohol with given weights of pure water, and after allowing the mixtures to remain for 24 hours, took the specific gravity of each at the temperature of 68°. The following table exhibits the result of these experiments. The first two columns contain the proportion of alcohol and water (in weight) mixed together, and the third the specific gravity of the mixture at 68°. I have added a fourth column, containing the specific gravity at 60°, the temperature commonly preferred in this country.*

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* Crell's Annals, 1796, i. 202.

Table of the strength of alcohol of various densities.

100 Parts.		Sp. Gravity.		100 Parts.		Sp. Gravity.	
Alcoh.	Wat.	at 68°.	at 60°.	Alcoh.	Wat.	at 68°.	at 60°.
100	—	791	796	55	45	903	906
99	1	794	798	54	46	905	908
98	2	797	801	53	47	907	910
97	3	800	804	52	48	909	912
96	4	803	807	51	49	912	915
95	5	805	809	50	50	914	917
94	6	808	812	49	51	917	920
93	7	811	815	48	52	919	922
92	8	813	817	47	53	921	924
91	9	816	820	46	54	923	926
90	10	818	822	45	55	925	928
89	11	821	825	44	56	927	930
88	12	823	827	43	57	930	933
87	13	826	830	42	58	932	935
86	14	828	832	41	59	934	937
85	15	831	835	40	60	936	939
84	16	834	838	39	61	938	941
83	17	836	840	38	62	940	943
82	18	839	843	37	63	942	945
81	19	842	846	36	64	944	947
80	20	844	848	35	65	946	949
79	21	847	851	34	66	948	951
78	22	849	853	33	67	950	953
77	23	851	855	32	68	952	955
76	24	853	857	31	69	954	957
75	25	856	860	30	70	956	958
74	26	859	863	29	71	957	960
73	27	861	865	28	72	959	962
72	28	863	867	27	73	961	963
71	29	866	870	26	74	963	965
70	30	868	871	25	75	965	967
69	31	870	874	24	76	966	968
68	32	872	875	23	77	968	970
67	33	875	879	22	78	970	972
66	34	877	880	21	79	971	973
65	35	880	883	20	80	973	974
64	36	882	886	19	81	974	975
63	37	885	889	18	82	976	
62	38	887	891	17	83	977	
61	39	889	893	16	84	978	
60	40	892	896	15	85	980	
59	41	894	898	14	86	981	
58	42	896	900	13	87	983	
57	43	899	903	12	88	985	
56	44	901	904	11	89	986	

100 Parts.		Sp. Gravity.		100 Parts.		Sp. Gravity.	
Alcoh.	Wat.	at 68°.	at 60°.	Alcoh.	Wat.	at 68°.	at 60°.
10	90	987		4	96	995	
9	91	988		3	97	997	
8	92	989		2	98	998	
7	93	991		1	99	999	
6	94	992		—	100	1000	
5	95	994					

Mr. Tralles of the Berlin Academy published an elaborate set of experiments upon this subject in the year 1811.* The following table which exhibits the result of his experiments, I consider as deserving to be generally known, though, as he used volumes instead of weights, his experiments cannot be expected to possess the accuracy of those of Mr. Gilpin, which I shall give afterwards.

Tralles's table.

100 measures contain of alcohol	Sp. gravity at 60°.	Differences.	100 measures contain of alcohol	Sp. gravity at 60°.	Differences.
0	0·9991		27	0·9679	10
1	0·9976	15	28	0·9668	11
2	0·9961	15	29	0·9657	11
3	0·9947	14	30	0·9646	11
4	0·9933	14	31	0·9634	12
5	0·9919	14	32	0·9622	12
6	0·9906	13	33	0·9609	13
7	0·9893	13	34	0·9596	13
8	0·9881	12	35	0·9583	13
9	0·9869	12	36	0·9570	13
10	0·9857	12	37	0·9556	14
11	0·9845	12	38	0·9541	15
12	0·9834	11	39	0·9526	15
13	0·9823	11	40	0·9510	16
14	0·9812	11	41	0·9494	16
15	0·9802	10	42	0·9478	16
16	0·9791	11	43	0·9461	17
17	0·9781	10	44	0·9444	17
18	0·9771	10	45	0·9427	17
19	0·9761	10	46	0·9409	18
20	0·9751	10	47	0·9391	18
21	0·9741	10	48	0·9373	18
22	0·9731	10	49	0·9354	19
23	0·9720	11	50	0·9335	19
24	0·9710	10	51	0·9315	20
25	0·9700	10	52	0·9295	20
26	0·9689	11	53	0·9275	20

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* Gilbert's Annalen, xxxviii. 369.

100 measures contain of alcohol	Sp. gravity at 60°.	Differences.	100 measures contain of alcohol	Sp. gravity at 60°.	Differences.
54	0·9254	21	78	0·8685	27
55	0·9234	20	79	0·8658	27
56	0·9213	21	80	0·8631	27
57	0·9192	22	81	0·8603	28
58	0·9170	22	82	0·8575	28
59	0·9148	22	83	0·8547	28
60	0·9126	22	84	0·8518	29
61	0·9104	22	85	0·8488	30
62	0·9082	22	86	0·8458	30
63	0·9059	23	87	0·8428	30
64	0·9036	23	88	0·8397	31
65	0·9013	23	89	0·8365	32
66	0·8989	24	90	0·8332	33
67	0·8965	24	91	0·8299	33
68	0·8941	24	92	0·8265	34
69	0·8917	24	93	0·8230	35
70	0·8892	25	94	0·8194	36
71	0·8867	25	95	0·8157	37
72	0·8842	25	96	0·8118	39
73	0·8817	25	97	0·8077	41
74	0·8791	26	98	0·8034	43
75	0·8765	26	99	0·7988	46
76	0·8739	26	100	0·7939	49
77	0·8712	27			

The importance of this object, both for the purposes of revenue and commerce, induced the British Government to employ Sir Charles Blagden to institute a very minute and accurate series of experiments. An account of these was published by Blagden in the Philosophical Transactions for 1790; and a set of tables, exhibiting the result of them, was drawn up by Mr. Gilpin, who had performed the experiments, and published them in the Philosophical Transactions for 1794. The following table, extracted from these, contains the specific gravity of different mixtures of alcohol and water at every 5° of temperature from 30° to 100°. The alcohol employed as a standard was of the specific gravity 0·825 at the temperature of 60°; and was composed, according to the experiments of Mr. Gilpin, of 100 parts of alcohol of the specific gravity 0·814 and 4·5 of water. From the preceding table, we see that alcohol of ·825 is composed of

Gilpin's tables.

89 pure alcohol
11 water
100

Real *Specific Gravities at the different Temperatures.*

Heat.	Pure Alcohol.	100 alcohol 5 water.	100 alcohol 10 water.	100 alcohol 15 water.	100 alcohol 20 water.	100 alcohol 25 water.	100 alcohol 30 water.	100 alcohol 35 water.	100 alcohol 40 water.	100 alcohol 45 water.
30°	·83896	·84995	·85957	·86825	·87585	·88282	·88921	·89511	·90054	·90558
35	83672	84769	85729	86587	87357	88059	88701	89294	89839	90345
40	83445	84539	85507	86361	87134	87838	88481	89073	89617	90127
45	83214	84310	85277	86131	86905	87613	88255	88849	89396	89909
50	82977	84076	85042	85902	86676	87384	88030	88626	89174	89684
55	82736	83834	84802	85664	86441	87150	87796	88393	88945	89458
60	82500	83599	84568	85430	86208	86918	87569	88169	88720	89232
65	82262	83362	84334	85193	85976	86686	87337	87938	88490	89006
70	82023	83124	84092	84951	85736	86451	87105	87705	88254	88773
75	81780	82878	83851	84710	85496	86212	86864	87466	88018	88538
80	81530	82631	83603	84467	85248	85966	86622	87228	87776	88301
85	81291	82396	83371	84243	85036	85757	86411	87021	87590	88120
90	81044	82150	83126	84001	84797	85518	86172	86787	87360	87889
95	80794	81900	82877	83753	84550	85272	85928	86542	87114	87654
100	80548	81657	82639	83513	84308	85031	85688	86302	86879	87421

Book II.
Division I.

Real Specific Gravities at the different Temperatures.

Heat.	100 alcohol 50 water.	100 alcohol 55 water.	100 alcohol 60 water.	100 alcohol 65 water.	100 alcohol 70 water.	100 alcohol 75 water.	100 alcohol 80 water.	100 alcohol 85 water.	100 alcohol 90 water.	100 alcohol 95 water.
30°	·91023	·91449	·91847	·92217	·92563	·92889	·93191	·93474	·93741	·93991
35	90811	91241	91640	92009	92355	92680	92986	93274	93541	93790
40	90596	91026	91428	91799	92151	92476	92783	93072	93341	93592
45	90380	90812	91211	91584	91937	92264	92570	92859	93131	93382
50	90160	90596	90997	91370	91723	92051	92358	92647	92919	93177
55	89933	90367	90768	91144	91502	91837	92145	92436	92707	92963
60	89707	90144	90549	90927	91287	91622	91933	92225	92499	92758
65	89479	89920	90328	90707	91066	91400	91715	92010	92283	92546
70	89252	89695	90104	90484	90847	91181	91493	91793	92069	92333
75	89018	89464	89872	90252	90617	90952	91270	91569	91849	92111
80	88781	89225	89639	90021	90385	90723	91046	91340	91622	91891
85	88605	89043	89460	89843	90209	90558	90882	91186	91465	91729
90	88376	88817	89230	89617	89988	90342	90668	90967	91248	91511
95	88146	88588	89003	89390	89763	90119	90443	90747	91029	91290
100	87915	88357	88769	89158	89536	89889	90215	90522	90805	91066

Real Specific Gravities at the different Temperatures.

Heat.	100 alcohol 100 water.	95 alcohol 100 water.	90 alcohol 100 water.	85 alcohol 100 water.	80 alcohol 100 water.	75 alcohol 100 water.	70 alcohol 100 water.	65 alcohol 100 water.	60 alcohol 100 water.	55 alcohol 100 water.
30°	·94222	·94447	·94675	·94920	·95173	·95429	·95681	·95944	·96209	·96470
35	94025	94249	94484	94734	94988	95246	95502	95772	96048	96315
40	93827	94058	94295	94547	94802	95060	95328	95602	95879	96159
45	93621	93860	94096	94348	94605	94871	95143	95423	95705	95993
50	93419	93658	93897	94149	94414	94683	94958	95243	95534	95831
55	93208	93452	93696	93948	94213	94486	94767	95057	95357	95662
60	93002	93247	93493	93749	94018	94296	94579	94876	95181	95493
65	92794	93040	93285	93516	93822	94099	94388	94689	95000	95318
70	92580	92828	93076	93337	93616	93898	94193	94500	94813	95139
75	92364	92613	92865	93132	93413	93695	93989	94301	94623	94957
80	92142	92393	92646	92917	93201	93488	93785	94102	94431	94768
85	91969									
90	91751									
95	91531									
100	91310									

Book II.
Division I.

Real Specific Gravities at the different Temperatures.

Heat.	50 alcohol 100 water.	45 alcohol 100 water.	40 alcohol 100 water.	35 alcohol 100 water.	30 alcohol 100 water.	25 alcohol 100 water.	20 alcohol 100 water.	15 alcohol 100 water.	10 alcohol 100 water.	5 alcohol 100 water.
30°	·96719	·96967	·97200	·97418	·97635	·97860	·98108	·98412	·98804	·99334
35	96579	96840	97086	97319	97556	97801	98076	98397	98804	99344
40	96434	96706	96967	97220	97472	97737	98033	98373	98795	99345
45	96280	96563	96840	97110	97384	97666	97980	98338	98774	99338
50	96126	96420	96708	96995	97284	97589	97920	98293	98745	99316.
55	95966	96272	96575	96877	97181	97500	97847	98239	98702	99284
60	95804	96122	96437	96752	97074	97410	97771	98176	98654	99244
65	95635	95962	96288	96620	96959	97309	97688	98106	98594	99194
70	95469	95802	96143	96484	96836	97203	97596	98028	98527	99134
75	95292	95638	95987	96344	96708	97086	97495	97943	98454	99066
80	95111	95467	95826	96192	96568	96963	97385	97845	98367	98991

By the excise laws at present existing in this country, the duty on spirits is levied by the bulk, estimated at a particular strength, to which all spirits of whatever strength are brought by means of a set of tables calculated. This strength is regulated by a very inconvenient hydrometer, invented in 1730 by Mr. Clarke,* since which time it has undergone various changes and improvements. This instrument was adapted to a very absurd kind of language, which had previously come into common use among dealers, and seems from them to have made its way into the excise laws. A mixture of equal bulks of alcohol and water was called *proof spirit,* and sometimes *double spirit.* Clarke's hydrometer consists of a thin copper ball, terminating above in a flat, slender stem, and below, in a metallic button, to keep it perpendicular. It is so light as to swim in pure alcohol. There is a mark upon the middle of the stem; and small weights accompany the instrument, to be put on in order to suit the various temperatures of the liquid. There is a weight marked *proof,* so adjusted that when it is placed upon the stem along with the proper weight for the temperature, the stem sinks till the mark on the middle of it is on a level with the surface of the liquid.

From an act of parliament passed in 1762, we learn that, at the temperature of 60°, the specific gravity of *proof spirit* ought to be 0·916. But Clarke's hydrometer, loaded with the proper weights, sinks to the mark indicating *proof* in spirits of the specific gravity 0·920, at the same temperature. From the table of Lowitz, given above, we learn that a mixture of equal weights of water and pure alcohol has the specific gravity ·917 at 60°. The legal proof spirit differs but little from this; Clarke's proof consists of 49 parts of pure alcohol and 51 of water. The near coincidence of these numbers to the truth indicates a considerable approach to accuracy. Had Sir Charles Blagden made choice of an alcohol of ·800 for his standard, the specific gravity of proof spirit would have been found to deviate very little from that of Clarke. But if by proof spirit were to be understood equal *bulks* of water and alcohol, as was doubtless the case, then both the legal and Clarke's proof differ very far from the truth.

The strength of spirits stronger than *proof,* or *over-proof,* as it is termed, is indicated on Clarke's hydrometer by the bulk of water necessary to reduce a given bulk of spirits to the spe-

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* See the first description of it in Phil. Trans. 1730. vol. xxxvi. p. 277.

cific gravity denominated proof. Thus, if one gallon of water be required to bring 20 gallons of the spirits to proof, it is said to be *one to* 20 *over-proof;* if one gallon of water be necessary to bring 15, 10, 5, or 2 gallons of the spirits to proof, it is said to be 1 to 15, 1 to 10, 1 to 5, 1 to 2 respectively, over-proof, and so on.

The strength of spirits weaker than proof, or *under-proof*, is estimated by the quantity of water which it would be necessary to abstract, in order to bring the spirits in question up to proof. Thus, if from 20 gallons of the spirits one gallon of water must be abstracted to bring it to proof, it is said to be *one in* 20 *under-proof;* if from 15, 10, 5, 2, &c. gallons of the spirits, one gallon of water must be abstracted to bring it to proof, it is said to be respectively 1 in 15, 1 in 10, 1 in 5, 1 in 2, &c. under-proof.

The following table points out the specific gravity of spirits of the various strengths indicated by Clarke's hydrometer at the temperature of 60.*

Degrees of Clarke's hydrometer.

Degrees.	Sp. gravity.	Degrees.	Sp. gravity.
1 in 2	9644	1 to 20	9162
1 — 3	9543	1 — 15	9135
1 — 4	9458	1 — 10	9107
1 — 5	9424	1 — 9	9093
1 — 6	9385	1 — 8	9071
1 — 7	9364	1 — 7	9047
1 — 8	9344	1 — 6	9006
1 — 9	9334	1 — 5	8961
1 —10	9320	1 — 4	8913
1 —15	9280	1 — 3	8817
1 —20	9265	1 — 2	8590
Proof	9200	Alcohol	8338

To remove all confusion from the duties on spirits, they ought to be levied by the weight, and not by the bulk. This might be done with sufficient accuracy either by actual weighing, or by constructing tables indicating the weight from the bulk and specific gravity.

The importance of this subject induces me to give one more table on account of its utility. It exhibits the specific gravity at every degree of temperature from 30° to 80° of a mixture of 100 parts of Gilpin's standard alcohol, and 65·6486 parts of water by weight. This mixture constitutes spirits 8 per cent. above-proof, according to the language of Sykes' hydrometer, or 1 to 10 above-proof by Clarke.

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* Wilson's Tables, p. 1.

Temp	Sp. gravity.	Temp.	Sp. gravity.	Temp.	Sp. gravity.	Temp.	Sp. gravity.
30°	0·92206	43°	0·91659	56°	0·91090	69°	0·90519
31	0·92165	44	0·91616	57	0·91046	70	0·90471
32	0·92124	45	0·91573	58	0·91003	71	0·90428
33	0·92082	46	0·91531	59	0·90960	72	0·90382
34	0·92040	47	0·91488	60	0·90917	73	0·90336
35	0·91998	48	0·91445	61	0·90873	74	0·90290
36	0·91956	49	0·91403	62	0·90829	75	0·90243
37	0·91914	50	0·91359	63	0·90785	76	0·90197
38	0·91872	51	0·91314	64	0·90741	77	0·90151
39	0·91830	52	0·91269	65	0.90697	78	0·90104
40	0·91788	53	0·91224	66	0·90653	79	0·90058
41	0·91745	54	0·91176	67	0·90609	80	0·90012
42	0·91702	55	0·91134	68	0·90564		

Action of air and oxygen on alcohol.

5. Neither common air nor oxygen gas has any action on alcohol in moderate temperatures, whether in the liquid or gaseous state; but in high temperatures the case is different. When set on fire in the open air it burns all away with a blue flame, without leaving any residuum. Boerhaave observed, that when the vapour which escapes during this combustion is collected in proper vessels, it is found to consist of nothing but water. Junker had made the same remark: and Dr. Black suspected from his own observations, that the quantity of water obtained, if properly collected, exceeded the weight of the alcohol consumed. This observation was confirmed by Lavoisier; who found that the water produced during the combustion of alcohol exceeded the alcohol consumed by about $\frac{1}{7}$th part.* Mr. Saussure junior has shown that 100 parts of alcohol when burnt yield 132 parts of water.† A proof that it contains a considerable proportion of hydrogen as a constituent.

When the vapour of alcohol is mixed with oxygen gas in the proper proportion, the mixture detonates when presented to a lighted taper, or when fired by electricity, as a mixture of oxygen and hydrogen gases do. This fact seems to have been first observed by Dr. Ingenhousz, or at least his experiments on ether appear to have led to it.‡ The density of the vapour of alcohol is considerable, and hence the quantity of oxygen necessary to consume it is great. The products of the combustion are water and carbonic acid.§

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* Mem. Par. 1781, p. 493.

† Nicholson's Journal, xxi. 263.

‡ See his Experiences et Observations sur divers Objets de Phys. p. 173.

§ Cruikshank's, Nicholson's Quarto Jour. v. 205.

6. Alcohol has but little action on the simple combustibles. On hydrogen, carbon, and charcoal, it does not appear to have any effect.

Phosphuretted alcohol.

It dissolves a little phosphorus when assisted by heat. This phosphorized alcohol exhales the odour of phosphuretted hydrogen gas. When a little of it is dropped into a glass of water, a flame instantly makes its appearance, and waves beautifully on the surface of the water.* This phenomenon, which is occasioned by the emission of a little phosphuretted hydrogen gas, can only be observed when the experiment is performed in a dark room.

Sulphuretted alcohol.

When sulphur and alcohol are brought into contact in the state of vapour, they combine and form a reddish coloured liquid, which exhales the odour of sulphuretted hydrogen. This compound was first formed by the Count de Lauraguais, who employed the following process. Some flowers of sulphur were put into a large glass cucurbite, having a glass vessel in its centre, containing alcohol. A head was adjusted, the cucurbit placed in a sand-bath, and heat applied. The sulphur was volatilized, and the alcohol converted into vapour at once. These meeting together in the head, united and formed the red liquor wanted.† It was supposed by chemists that sulphur cannot be dissolved in alcohol, except by a similar process;‡ but from the experiments of Favre, this does not appear to be the case.§ He digested, during 12 hours, 1 part of flowers of sulphur in 8 parts of alcohol, of the specific gravity 0·837, in a heat not sufficient to produce boiling. The alcohol assumed a yellow colour, and acquired the smell and taste of sulphuretted hydrogen. Another portion of the same alcohol was digested for a month, cold, on sulphur. The effect was the same. On trying alcohol of various strengths from ·817 to ·867, he found, that the alcohol acted with more energy in proportion to its strength.

The sulphuretted alcohol prepared by Lauraguais' method contains about $\frac{1}{60}$th of sulphur. The sulphur is precipitated by water.

Action of alkalies,

7. Alcohol dissolves the fixed alkalies very readily, and forms

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* Brugnatelli, Ann. de Chim. xxiv. 71. This experiment was first made by Boyle. See Shaw's Boyle, iii. 196.

† Mem. Par. 1758, p. 9.

‡ See the Elemens de Chymie of the Dijon Academy, iii. 287. Fourcroy's Connoissances Chymiques, viii.

§ Gehlen's Jour. ii. 343.

with them a reddish-coloured acrid solution. It is from this solution only that these alkalies can be obtained in a state of purity. When heat is applied to it the alcohol may be distilled over. It appears however, to be partly decomposed; but the nature of the products has not been accurately ascertained. Ammonia also combines with alcohol with the assistance of heat: but at a temperature somewhat below the boiling point of alcohol, the ammonia flies off in the state of gas, carrying with it, however, a little alcohol in solution.

8. None of the earths are acted upon by alcohol, unless strontian and barytes be excepted. It absorbs about its own weight of nitrous gas, which cannot afterwards be expelled by heat.* Earths.

9. Of the acids, the sulphuric and nitric decompose alcohol; but all the other acids are soluble in it, except the metallic acids, and phosphoric acid. Acids.

10. Alcohol is capable of dissolving a great many saline bodies. A considerable number of these, with the quantities soluble, is exhibited in the following tables.† Salts.

I. SUBSTANCES DISSOLVED IN LARGE QUANTITIES.

Names of the substances.	Temperature.	240 parts of Alcohol dissolve
Persulphate of iron		
Nitrate of cobalt†	54·5°	240 parts
copper†	54·5	240
alumina†	54·5	240
lime‡		300
magnesia†	180·5	694
Muriate of zinc†	54·5	240
alumina†	54·5	240
magnesia†	180·5	1313
iron†	180·5	240
copper†	180·5	240
Acetate of lead	154·5	240
copper§		
Nitrate of zinc decomposed†		
iron decomposed†		
bismuth decomposed†		

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* Priestley, i. 379.

† Morveau, Jour. de Phys. 1785.

§ Withering, Phil. Trans. lxxii. 336.

II. SUBSTANCES DISSOLVED IN SMALL QUANTITIES.

Names of the Substances.	240 parts of Alcohol at the boiling temperature dissolve
Muriate of lime†	240 parts
Nitrate of ammonia†	214
Corrosive sublimate	212
Succinic acid†	177
Acetate of soda†	112
Nitrate of silver†	100
Refined sugar†	59
Boracic acid†	48
Nitrate of soda†	23
Acetate of copper†	18
Muriate of ammonia†	17
Arseniate of potash†	9
Oxalate of potash†	7
Nitrate of potash†	5
Muriate of potash†	5
Arseniate of soda†	4
White oxide of arsenic†	3
Tartrate of potash†	1
Nitrate of lead§	
Carbonate of ammonia§	

III. SUBSTANCES INSOLUBLE IN ALCOHOL.

Sugar of milk
Borax†
Tartar†
Alum†
Sulphate of ammonia†
    lime
    barytes§
    iron
    copper†
    silver†
    mercury
    zinc

Sulphate of potash†
    soda†
    magnesia†
Sulphite of soda
Tartrate of soda and potash
Nitrate of mercury†
Muriate of lead†
    silver‡
Common salt†
Carbonate of potash
    soda

These experiments were made chiefly by Macquer and Wenzel.* The alcohol employed by Macquer was of the specific

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[*] Verwandtschaft, p. 300. The solubility of all the salts marked † was ascertained by Wenzel; those marked ‡, by Macquer; and those marked §, by Withering.

gravity 0·840. Wenzel does not give the density of his alcohol; but as he compares it with that of Macquer, we may suppose it nearly of the same strength. As the solubility of salts depends upon the strength of the alcohol employed, the experiments of these chemists must be considered as defective, because they have confined themselves to one particular density. This defect is in part supplied by the following very valuable table of Mr. Kirwan's, constructed from his own experiments.*

Solubility of Salts in 100 parts of Alcohol of different Densities.

Salts.	Alcohol of				
	0·900	0·872	0.818	0·834	0·817
Sulphate of soda	0·	0·	0·	0·	0·
Sulphate of magnesia	1·	1·	0·	0·	0·
Nitrate of potash	2·76	1·		0·	0·
Nitrate of soda	10·5	6·		0·38	0·
Muriate of potash	4·62	1·66		0·38	0·
Muriate of soda	5·8	3·67		0·5	
Muriate of ammonia	6·5	4·75		1·5	
Muriate of magnesia dried at 120°	21·25		23·75	36·25	50·
Muriate of barytes	1·		0·29	0·185	0·09
Ditto crystallized	1·56		0·43	0·32	0·06
Acetate of lime	2·4		4·12	4·75	4·88

Its flame tinged by salts.

When alcohol containing certain saline bodies in solution is set on fire, its flame is often tinged of different colours according to the body. Thus nitrate of strontian tinges it purple; boracic acid and cupreous salts tinge it green; muriate of lime gives it a red colour; nitre and corrosive sublimate a yellow colour.

Composition.

11. Different opinions were entertained by chemists about

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* On Mineral Waters, p. 274.

the nature of alcohol. Stahl thought that it was composed of a very light oil, united by means of an acid to a quantity of water. According to Junker, it was composed of phlogiston, combined with water by means of an acid. Cartheuser, on the other hand, affirmed that it contained no acid, and that it was nothing else than pure phlogiston and water. But these hypotheses were mere assertions supported by no proof whatever. Lavoisier was the first who attempted to analyze it. He burnt a quantity of alcohol of the specific gravity 0·8293 in a glass jar, standing over mercury and filled with oxygen gas, and he calculated the constituents of the alcohol from the quantity of oxygen gas consumed, and the quantity of carbonic acid formed by the combustion of a given weight of alcohol.* But the results which he obtained by this process could not be accurate, because a quantity of the alcohol would evaporate without burning, and he had no means of determining the proportion which this quantity bore to the whole. In the year 1807 Mr. Theodore de Saussure resumed the investigation of the composition of alcohol. He tried the method of Lavoisier. He likewise detonated a mixture of vapour of alcohol and oxygen gas by means of electricity. But the method upon which he put the greatest reliance was to decompose alcohol by passing it through a red hot porcelain tube and to analyze the combustible gas which was produced.† The results which he obtained by these different processes differed considerably from each other. They were no doubt nearer the truth than those of Lavoisier; because considerable progress had been made in the art of analysis since the time of that philosopher. But they could be considered only as approximations. M. De Saussure turned his attention to this subject again in 1813, and published a new analysis of alcohol, which may be considered as approaching as nearly to precision as the present state of the science of chemistry will admit. He employed for his analysis, alcohol of the specific gravity 0·8302 at the temperature of 62·8°, obtained by rectifying common spirits. This alcohol was a compound of 13·8 water and 86·2 of the absolute alcohol of Richter; the water being subtracted from the products obtained, the residue gave the composition of the absolute alcohol of Richter. His method of analysis was to pass the alcohol through a red-hot porcelain tube, and along a glass tube near six feet in length surrounded with ice. All the pro-

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* Mem. Par. 1781.

† Nicholson's Journal, xxi. 225.

ducts were carefully collected and weighed. There was a little charcoal deposited in the porcelain tube and a very little oil in the glass tube. The water condensed amounted to $\frac{1000}{4464}$ of the weak alcohol employed, and it contained $\frac{1}{281 \cdot 5}$ of its weight of absolute alcohol. The combustible gas weighed 912·3 grains, (the weak alcohol employed was 1256·7 gr.) and there was a loss of 55·82 grains. The gas was burnt in a eudiometer with oxygen gas. The products were carbonic acid and water. For every 2 volumes of carbonic acid produced, 3 volumes of oxygen were consumed. Now this is the property of olefiant gas. Hence it follows, that the gas is precisely the same in its composition, as if it were a mixture of vapour of water and olefiant gas. The result of the analysis was, that the absolute alcohol of Richter is a compound of

Hydrogen	13·70
Carbon	51·98
Oxygen	34·32
	100·00

Or the composition may be thus stated,

Olefiant gas	61·63
Water	38·37
	100·00

If we suppose it a compound of 1 volume of olefiant gas and 1 volume of vapour of water reduced to 1 volume, its specific gravity when in the state of vapour will be just equal to the specific gravity of these two elastic fluids added together. Now the specific gravity of these bodies is

Olefiant gas	0·974
Vapour of water	0·625
	1·599

And the specific gravity of the vapour of alcohol as determined by Gay-Lussac is 1·6133, which almost coincides with the preceding result. On this supposition the composition of alcohol will be as follows:

Olefiant gas	29·6094	60·83	100	1·750
Vapour of water	19·0625	39·17	64·38	1·125

Hence it is a compound of 1 atom of olefiant gas and 1 atom of water. So that the constitution of alcohol may be stated as follows:

3 atoms hydrogen	.. =	0·375
2 atoms carbon	..... =	1·5
1 atom oxygen	.... =	1·0
		2·875

So that it is a compound of 6 atoms, and an integrant particle of it weighs 2·875.

CHAP. II.

OF ETHERS.

When alcohol is mixed with various acids and subjected to distillation, a fragrant and very volatile liquid is obtained imperfectly soluble in water. This liquid is distinguished by the name of *Ether*. As the properties of the ether vary with the acid employed to form it, each species is distinguished by prefixing the name of the acid by means of which it is formed. Thus *sulphuric ether* means ether formed by means of sulphuric acid. In like manner *nitric ether*, *muriatic ether*, *acetic ether* indicate ethers formed by means of nitric, muriatic, and acetic acids. We are at present acquainted with seven different species of ethers, namely,

Species.

1. Sulphuric ether.
2. Nitric ether.
3. Chloric ether.
4. Muriatic ether.
5. Hydriodic ether.
6. Acetic ether.
7. Formic ether.

These different species will constitute the subject of the seven following sections.

SECT. I.

OF SULPHURIC ETHER.

History.

The method of making sulphuric ether is described in the dispensatory of Valerius Cordus, published at Nuremberg about the year 1540: from which Conrad Gesner transcribed it into his *Thesaurus Euonymi de Remediis Secretis*, published in 1552, where it is called *Oleum Vitrioli dulce.*[*] It appears to have been known, though not in a state of purity, both to Basil Valentine and Paracelsus. But in the writings of chemists published about the end of the 17th century, I have not been able to find any traces of it,[†] except in those of Mr. Boyle. He was evidently acquainted with it, as appears from different passages of his writings,[‡] though he no where describes it particularly. But it was a paper in the Philosophical Transactions for 1730, by a German who called himself Dr. Frobenius, describing several of its most singular properties, that first drew the attention of chemists to this curious liquor.[§] In this paper it first received the name of

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[*] Whoever will consider the formula given for preparing this *Oleum Vitrioli dulce* by Gesner, will be satisfied that it was very different from the *dulcified acids* of the moderns, and that it must have been a mixture of *alcohol, ether*, and *sweet oil of wine*. The following is the passage of Gesner, as quoted by Hoffman, from whom has been taken the historical facts respecting the knowledge of ether possessed by the alchymistical writers.—"Recipe vini ardentis acerrimi et ter sublimati uncias quinque, olei vitrioli austeri tantundem, misce in venetiano vitro, et pone in cucurbitam parvam angusto orificio, et luto optimo orificium claude, dimitte ita per integrum mensem aut duos. Deinde effunde in cucurbitam, cui sit immediate annexum alembicum, cujus figuram subjiciemus, pone deinde in parvam fornacem, ac dimidiam ejus partem cinere obrue, postea applica recipientem et luto juncturam claude diligenter, et extrahe uncias sex vini ardentis quas infudisti. Ut vero tutius hoc fiat, pone in balneum Mariæ; sic solum vinum absque oleo ascendet. Cum extraxeris autem per balneum infusas uncias sex vini usti, pone id, quod residuum est, in fornacem, ut arena mediam cucurbitæ partem attingat, ac novo et vacuo recipiente eoque non magno applicato, luto juncturam diligenter claude. Accende deinde modestum ignem, et sensim extrahe omnem humiditatem quæ relicta est in cucurbita, donec nihil humidi amplius in fundo appareat; adhibita semper maxima cura et diligentia, ut ignem ita modereris, ne ebulliat usque ad alembici canalem. Nam si hunc ebullitio attigerit, sedare non potes, neque prohibere, quin in receptaculum egrediatur, ac totum oleum perdat; solet enim facillime ebullire. Tum videbis duo contineri in eo, aqueum videlicet humorem ac pinguem; segregabis vero unum ab altero statim, ita ut nihil aqueum in oleo relinquatur, nam aqua illa oleum corrumpit; segregatum oleum usui reserva."

[†] The *Oleum Vitrioli dulce* of Lemery, for instance, is very different from that described by Gesner. (See his Cours de Chymie, p. 502.)

[‡] See Shaw's Boyle, i. 530; and i. 269; where the process for making ether, and some of its most remarkable properties, are detailed at length.

[§] Phil. Trans. xxxvi. 283. This paper is little else than a rhapsody in the alchymistical style. At the end of it there is a note by Mr. Godfrey, (Hankwitz,) Mr. Boyle's operator, mentioning the experiments formerly made upon it by Mr. Boyle and Sir Isaac Newton.

Book II. Division I.

ether. The German chemists long distinguished it by the name of *naphtha.*

Preparation.

1. Sulphuric ether is usually prepared by the following process:* A mixture of equal parts of alcohol and sulphuric acid is put into the retort, to which a large receiver is then luted. It is proper to surround the receiver with ice, or at least with cold water. Heat is applied; and as soon as the mixture boils, the ether comes over and is condensed, and runs in large striæ down the sides of the receiver. As soon as it amounts to one half of the alcohol employed, the process must be stopped. The ether, thus obtained, is not quite pure, almost always containing a little sulphureous acid.

The separation of the liquid from the sulphureous acid, with which it is mixed, is called the *rectification of the ether.* The usual method, and I may add, the best, is the following, first employed by Mr. Wolfe: Fill three-fourths of a bottle with the impure ether, add a little water and a portion of slacked lime. Agitate the bottle with violence, and keep it for some time in water before taking out the cork. If the smell of the acid be not removed, add a little more lime, and agitate a second time. Decant off the ether into a retort, and distil it over.†

The ether procured by this process is not quite pure, even after all the acid has been removed. The first portion of liquid that comes over during the distillation is merely alcohol impregnated with a little ether. Common ether is in reality a mixture of ether and alcohol. The usual method of separating this liquid is by mixing the ether with water, and then proceeding to distillation with a very moderate heat. But Mr. Lowitz has shown that this method does not succeed. The following process yielded him an ether much purer than any that had been previously obtained. Into 16 parts of ether, of the specific gravity ·775 in the temperature of 60°, he threw dry powdered salt of tartar, till the last portions were no longer wetted by the liquor. The mixture being allowed to digest, the ether was then drawn off. Its specific gravity was now only ·746. By this means it was deprived of the water which it contained. To remove the alcohol, dry pow-

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* Frobenius' process was first published in the Philosophical Transactions, vol. xli.

† Proust, Ann. de Chim. xlii. 256.

Subdiv. VI. Chap. II.

dered muriate of lime was thrown into the liquid in the same manner, as long as it would dissolve. On standing, the mixture separated into two portions; the alcohol holding the salt in the solution sunk to the bottom; the ether swam on the surface. When separated from the inferior liquor, its specific gravity was now only ·632 in the temperature of 60°. It was, therefore much purer than any former ether described by chemists, since it never before had been procured lighter than 0·725.[*] The ether thus prepared contains a little of the salt, from which it may be freed by distillation. But in that case its specific gravity increases. The reason seems to be, that the purest portion of the ether assumes the form of elastic fluid. M. Theodore de Saussure purified ether by nearly the same process, excepting that he distilled it off the muriate of lime. He obtained it of the specific gravity 0·7155 at the temperature of 68°.[†]

Properties.

2. Ether, thus obtained, is a limpid and colourless liquor, of a very fragrant smell, and a hot pungent taste.

It is so volatile that it can scarcely be poured from one vessel to another without losing a considerable portion of it by evaporation. When poured out in the open air, it disappears in an instant; and, during its evaporation, produces a very considerable degree of cold. If a glass vessel containing water, and surrounded with a cloth, be dipped into ether, two or three times, and the ether each time be allowed to evaporate from the cloth, the water in the glass freezes. In the open air ether boils at 98°, and in a vacuum at – 20°. Were it not, therefore, for the pressure of the atmosphere it would always exist in the gaseous state.

When exposed to the open air it speedily assumes the gaseous form. This happens, for instance, if a little of it be poured into a glass phial. The vapour of ether displaces a considerable portion of the air of the phial, and is not soon dissipated. Ingenhousz has shown that the specific gravity of this vapour is very considerable.[‡]

Mr. Dalton has found it 3·125, the specific gravity of common air being 1.[§] Gay-Lussac has determined the specific gravity of this vapour with much care. According to his

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[*] Lowitz, Crell's Annals, 1796, i. 429.

[†] Annals of Philosophy, iv. 40.

[‡] See his Nouvelles Experiences, p. 180.

[§] Manchester Memoirs, iii. 260. Second Series.

experiments, it is 2·5860, that of air being 1.[*] This is about a fifth part less than the determination of Mr. Dalton. I consider the true specific gravity to be 2·5666.

Ether, when exposed to a cold of — 46°, freezes and crystallizes.[†]

3. Neither oxygen gas nor common air produce any effect upon ether in moderate temperatures; but in high temperatures the case is very different. Ether is exceedingly inflammable, and when kindled in the state of vapour burns with rapidity, with a fine white flame, and leaves behind it a trace of charcoal. During its combustion carbonic acid is generated. How well soever it has been rectified, it always exhibits traces of sulphuric acid.[‡]

When ether is admitted to any gaseous body standing over mercury, it always doubles the bulk of the gas, as Dr. Priestley first observed. If oxygen gas, thus expanded by ether, be presented to a lighted candle, the ether burns with great rapidity, but produces no explosion. But if one part in bulk of this expanded oxygen be mixed with three parts of pure oxygen gas, and kindled, a very loud explosion takes place: the products are water and $2\frac{1}{2}$ parts of carbonic acid.[§] Mr. Cruickshanks, to whom we are indebted for this instructive experiment, ascertained, that one part of the vapour of ether takes 6·8 parts of oxygen gas to consume it completely; and from the relative proportions of the two products, he has shown that the carbon which ether contains is to its hydrogen as five to one.

According to Dalton, one volume of ether requires for its combustion 6 volumes of oxygen; the residue consists of 4 volumes of carbonic acid.[||]

Composition.

Now it is obvious that 4 volumes of the oxygen gas must have gone to the formation of carbonic acid gas; the remaining two volumes of oxygen must have gone to the formation of water, and they must have united with a quantity of hydrogen; which, had it been in the gaseous state would have amounted to 4 volumes. Carbonic acid gas contains its own volume of carbon in the gaseous state. It follows, there-

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[*] Ann. de Chim. et Phys. i. 218.

[†] Fourcroy and Vauquelin, Ann. de Chim. xxix. 289.

[‡] Scheele, ii. 108.

[§] Cruickshanks, Nicholson's Journal, v. 205.

[||] Manchester Memoirs, iii. 179. Second Series.

fore, from the preceding facts that 1 volume of vapour of ether contains

$\left.\begin{array}{l}\text{4 volumes carbon,}\\ \text{4 volumes hydrogen,}\end{array}\right\}$ condensed into 1 volume.

The specific gravity of vapour of carbon is 0·416, that of hydrogen gas 0·0694. Hence

4 volumes carbon weigh	1·664
4 volumes hydrogen	0·277
Total ...... =	1·941
Specific gravity of ether vapour ..	2·586
Remainder .... =	0·645

From this statement it appears that the weight of the ether vapour exceeds that of carbon and hydrogen detected in it by the analysis by 0·645, a number which amounts almost exactly to ¼th part of the weight of the ether vapour. Now this deficiency can be ascribed to nothing else than water. Hence it follows that three fourths of the weight of ether vapour must be carbon and hydrogen, and the other fourth vapour of water. Now 4 volumes carbon and 4 volumes hydrogen are in the proportions which constitute olefiant gas, and they are equivalent to two atoms of olefiant gas. But

2 atoms of olefiant gas weigh	3·5
An atom of water weighs	1·125
Total .... =	4·625

Now 1·125 is very nearly the fourth part of 4·625. Hence it seems to follow from Dalton's analysis that ether is a compound of two atoms of olefiant gas, and 1 atom of the vapour of water.

But the specific gravity of two atoms of olefiant gas is

= 0·9708 × 2 .... =	1·9416
While that of 1 volume vapour is ... =	0·6250
Total .... =	2·5666

But 2·5666 comes very near 2·586, the numerical result obtained by Gay-Lussac. Hence I am disposed to consider the above statement respecting the composition of sulphuric ether to be the true one. It is a compound of

$\left.\begin{array}{l}\text{2 volumes olefiant gas,}\\ \text{1 volume vapour of water,}\end{array}\right\}$ reduced into 1 volume.

Its specific gravity is 2·5666, and it is composed of

5 atoms hydrogen	= 0·625
5 atoms carbon	= 3·000
1 atom oxygen	= 1·000
	4·625

So that an integrant particle of it weighs 4·625.

M. Theodore de Saussure attempted to analyze sulphuric ether by the very same process as the preceding. The following is the result of his experiments. Ether is composed of

Hydrogen	14·40
Carbon	67·98
Oxygen	17·62
	100·00

Now these proportions are equivalent to

Olefiant gas ..	80·05	100
Water	19·95	25
	100·00*	

It appears from this analysis that ether is composed of 4 parts, by weight, of olefiant gas and 1 part of water.

But I consider the result deduced from Dalton's analysis as the true one. It was the conclusion to which I had come long before Mr. Dalton published his experiments.

Ingenhousz was the first who ascertained that the vapour of ether detonates with common air and oxygen gas. His account of the experiment was first published in a letter to Dr. Priestley, in one of the original volumes of that philosopher *on air*, and likewise in the 69th volume of the Philosophical Transactions. His method was exceedingly simple. A single drop of ether, let fall into a bottle holding about 10 cubic inches of air, gives it the property of detonating. Too much ether destroys the detonation. With oxygen gas the same method succeeds.†

Action of heat.

When ether, in the state of vapour, is made to pass through a red-hot porcelain tube, it is decomposed completely, and a great quantity of carburetted hydrogen gas is obtained.‡ Saussure, junior, repeated the experiment with precision. He

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[*] Annals of Philosophy, iv. 40.

[†] See Ingenhousz' Experiences, p. 171.

[‡] Dutch Chemists, Jour. de Phys. xlv. 184.

passed 1103 parts of the ether through a red-hot porcelain tube; the products were as follows: $5\frac{1}{4}$ parts of charcoal in the tube, 3 parts of volatile oil crystallized in thin scales and smelling of benzoin; 43 parts of a volatile oil nearly black, partly fluid and partly of the consistence of honey; 3 parts of water and 948 parts of heavy inflammable air. The loss, amounting to 100·75 parts, was chiefly owing to the escape of oil in the state of vapour.*

4. Ether does not combine with water in any proportion: when the liquids are shaken together, they separate again; but the water retains a portion of the ether, while the ether on the other hand, remains united to a part of the water. From the experiments of the Count de Lauraguais, we learn that ten parts of water take up one of ether.† Alcohol, on the other hand, unites with ether in any proportion whatever.

Dissolves phosphorus

5. Of the simple combustibles, ether seems to act only on phosphorus and sulphur.

It is capable of dissolving a small proportion of phosphorus. The solution is transparent; but the addition of a little alcohol to it renders it milky. This furnishes us with a method of ascertaining whether ether be sophisticated with alcohol.‡

And sulphur.

Ether was supposed incapable of acting on sulphur, except when both were in the state of vapour, according to the experiments of Lauraguais; but Favre has shown that a solution may be obtained by digesting flowers of sulphur in cold ether, and that the solvent power of the ether is promoted by exposure to the light. By a month's digestion, he dissolved nearly one part of sulphur in 12 of sulphuric ether; the solution was nearly colourless, but had the taste and smell of sulphuretted hydrogen.§

6. Ether has no action on metals, but revives those that have a weak affinity for oxygen when mixed with their solution in acids, as gold and silver. It dissolves the muriate of gold and corrosive sublimate.

7. It is probable that it has no action on fixed alkalies and earths; but it combines, or at least mixes readily with ammonia.

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* Nicholson's Journal, xxi. 323.

† Mem. Par. 1758. From his experiments it seems to follow, that the portion taken up by water is not ether, but a substance which may be obtained in crystals by evaporation.

‡ Brugnatelli, Ann. de Chim. xxiv. 73.

§ Gehlen's Jour. iv. 227.

It absorbs nitrous gas in considerable quantity.

Action of acids.

8. Sulphuric acid seems capable of converting it into a peculiar kind of oil known by the name of sweet oil of wine.

If we fill a bottle capable of holding three or four English pints with chlorine gas, taking care to expel the water as completely as possible, and then throw into it about a dram, or half a dram, of good ether, covering its mouth immediately with a piece of light wood or paper, in a few seconds white vapour will be perceived moving circular in the bottle: this will be soon followed by an explosion accompanied with flame; at the same time a very considerable quantity of charcoal will be deposited, and the bottle will be found to contain carbonic acid gas.* The action of the other acids upon ether has not been examined with attention.

9. Ether dissolves the fixed and volatile oils, bitumens, those at least which are fluids, and resins; but it does not act upon gum.†

Constitution.

10. When we compare the constituents of alcohol and sulphuric ether with each other, the only difference between them is, that ether contains less vapour of water than alcohol by about one-half.

11. From the experiments of Boullay, we learn that sulphuric ether may be prepared likewise by substituting phosphoric‡ or arsenic§ acid in place of sulphuric. This serves still farther to confirm the preceding theory of the formation of this ether.

SECT. II.

OF NITRIC ETHER.

Nitric ether is first mentioned in an epistle written by Kunkel to Voight, and published in 1681; || but no attention was paid to it by succeeding chemists till it was discovered a second time by Navier in 1742,** and a third time by Sebastiani in 1746.††

Preparation.

The method of preparing it, proposed by Navier, was this: twelve parts of alcohol are put into a strong bottle, which is

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* Cruickshanks, Nicholson's Jour. v. 205.

† Elemens de Chymie by the Dijon Academy, iii. p. 318.

‡ Ann. de Chim. lxii. 192.

§ Ibid. lxxviii. 284.

|| Epistola contra Spiritum Vini sine Acido.

** Mem. Par. 1742.

†† Diss. de Nitro, 1746.

kept surrounded with water, or rather with ice: eight parts of nitric acid are poured in at intervals, the mixture being agitated after every addition. The bottle is then well corked, and the cork secured by leather. Ether gradually forms at the surface of the liquid. After five or six days, when the formation is supposed to be over, the cork is to be pierced with a needle, to allow a quantity of nitrous gas to escape, which would otherwise carry the ether along with it. The cork is then to be drawn; the whole liquid is to be poured into a funnel, and by means of the finger the liquid below is allowed to run out while the ether is retained.

This method is somewhat hazardous; for the quantity of nitrous gas evolved is so great as often to burst the bottle. Dr. Black substituted in place of it a very ingenious process. He put into a glass phial the proper quantity of nitric acid; over this was poured gently a stratum of water, and the alcohol was poured over all. Thus there were three strata of liquids in the vessel: the acid lowermost, and the alcohol uppermost, separated from each other by the water. The acid and alcohol gradually combined with the water, and coming into contact acted on each other without violence; and thus the ether was formed without risk.

Dehne has given another process for obtaining nitric ether exceedingly tedious, but not attended with any risk. The alcohol is put into a tubulated retort, to which a large receiver is luted; $\frac{1}{48}$th part of nitric acid is be added every four hours, drop by drop, till it amounts to about half the weight of alcohol; then the mixture becomes hot, and the ether passes over into the receiver. After this a little more nitric acid is to be added every morning and evening. Ether gradually forms on its surface. The acid is to be added till it falls down to the bottom of the retort in the form of green globules, indicating the perfect saturation of the acid with nitrous gas. This is a proof that no more ether will be formed.

Various other methods of preparing nitrous ether have been proposed by chemists, as the distillation of a mixture of sulphuric acid, nitre, alcohol, &c. But the process preferred by artists is that of Chaptal as corrected by Proust. A large retort is luted to a glass globular vessel furnished with a tube of safety. From this globe a tube passes to a second, likewise furnished with a tube of safety; and to this last vessel is connected three Woulfe's bottles in the usual way, which must be half full of alcohol. A mixture of 32 parts of alcohol and

24 of acid, of the specific gravity 1·3, is put into the retort. The heat of a chaffing dish is applied, and removed as soon as the effervescence begins. The greatest part of the ether is detained by the alcohol in the first Woulfe's bottle. This mixture is to be saturated with an alkali, and the ether separated by distillation.*

These processes are all of them so defective and complicated, that little precise knowledge was acquired of nitric ether, till Thenard undertook an investigation of it in 1807. He distilled a mixture of alcohol and nitric acid, and carefully collected and examined all the products both liquid and gaseous. A considerable part of the ether formed he found made its escape in the gaseous form, while the liquid in the receiver, hitherto considered nitric ether, was a mixture of alcohol, water, ether, nitrous, and acetic acids. These results led him to the following method of procuring pure nitric ether.

Thenard's process.

Equal weights of alcohol and nitric acid, of the specific gravity 1·283, were put into a retort. To the beak of the retort was luted a glass tube, which was plunged to the bottom of a long narrow glass jar half filled with a saturated solution of common salt in water. From the top of this jar passed another tube, which went to the bottom of another similar jar, likewise half filled with a solution of common salt. In this manner five similar jars were connected with each other, each half filled with a saturated solution of common salt. From the last a tube passed to a water trough to receive the gaseous products in proper jars. Each of these five jars was surrounded with a mixture of snow and salt to keep it as cool as possible. A moderate heat being applied to the retort a violent effervescence began. It was found necessary to withdraw the fire, and even to moisten the outside of the retort with water, in order to prevent the vessels from bursting. The gaseous matter evolved was thus forced to pass through the

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* Proust, Ann. de Chim. xlii. 262.—Brugnatelli has proposed the following method; but I find that the proportion of ether obtained by it is much smaller than the other processes, though Brugnatelli affirms the reverse. Put an ounce of sugar into a retort, and pour over it two ounces of alcohol. Lute to it a large receiver with slips of paper, and then add three ounces of nitric acid. The sugar is dissolved, the mixture boils, and the ether passes over pure, equal in weight to the alcohol. See Jour. de Chim. iii. 68.—Perhaps my want of complete success was owing to the use of a stronger acid than that employed by Brugnatelli.

different jars containing the common salt solution, and there it deposited the greatest part of its ether. The ether was found floating on the surface of the solutions in each, but the greatest part of it in the first jar. It was separated; and to free it from the nitrous and acetic acids with which it was contaminated, it was agitated in a close phial with a sufficient quantity of chalk, till it ceased to produce any change on vegetable blues. It was then decanted off. Thus purified it possessed the following properties.

Properties of nitric ether.

It had a slightly yellow colour, and a very strong ethereal odour. Its taste was strong and quite peculiar. It was rather heavier than alcohol, but much more volatile than sulphuric ether. Hence it only moistened bodies for a moment, and produced a very considerable degree of cold by its evaporation. The heat of the hand was sufficient to set it a boiling.

It was lighter than water, and required 48 parts of that liquid to dissolve it, and communicated to it an odour like that of apples. It dissolved in alcohol in every proportion. It burnt very brilliantly with a white flame like sulphuric ether. When kept for some time, both nitrous and acetic acids were formed in it. The same acids were evolved if the ether was heated, or if it was agitated with water. When brought in contact with a little of these acids, it instantly absorbed them, and acquired the property of converting vegetable blues into red.

When brought in contact with nitrous oxide, or any other gas, at the temperature of 70°, it instantly quintupled its bulk, being converted into vapour. At that temperature its vapour was capable of supporting a column of mercury 28·74 inches high. At the temperature of 70°, and when the barometer stands at 30 inches, it is liquid; but if we increase the heat or diminish the pressure, it assumes the state of vapour. It is much more elastic than sulphuric ether. At the temperature of 70°, the vapour of sulpuric ether is capable of sustaining a column of mercury only 16 inches high.

Such are the properties of nitric ether ascertained by Thenard.* They show us that it differs essentially from sulphuric ether. The gradual evolution of nitrous acid in it demonstrates that it must contain azote as one of its constituents. Thenard endeavoured to ascertain the proportion of its constituents by passing it through a red hot porcelain tube, and

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* Mem. d'Arcueil, i. 75.

examining the new substances evolved. They were water, carbonic acid, charcoal, oil, and a considerable quantity of gas which contained azote and nitrous gas, and a heavy inflammable air, which detonated with oxygen, and yielded carbonic acid and water. A little ammonia appeared also to have been produced. By estimating the weight of each of these substances and their constituents, Thenard concluded, that 100 parts of nitric ether was composed of

Composition.

48·52	oxygen
28·45	carbon
14·49	azote
8·54	hydrogen
100·00*	

But this analysis is liable to several exceptions. There was a considerable loss, and the composition of several of the substances evolved is not sufficiently determined. A better mode of analysis would have been, to have mixed the vapour of the ether with a sufficient quantity of oxygen, and to have decomposed it by electricity. By this method, knowing the specific gravity of the vapour, and the products furnished by its decomposition, it would have been easy to have deduced its constituents. I think it not improbable from analogy that nitric ether is in reality a compound of two atoms olefiant gas, with one atom nitric acid. On that supposition it would differ from sulphuric ether, simply by the substitution of nitric acid for water. Were this its composition its constitution would be

4 atoms hydrogen	=	0·50
4 atoms carbon	=	3·00
1 atom azote	=	1·75
5 atoms oxygen	=	5·00
		10·25

Thus its weight would be 10·25 and it would be a compound of no fewer than 14 atoms.

Gaseous products,

During the formation of nitric ether a vast quantity of gas is evolved. The Dutch chemists examined this gas, and considered it as a compound of nitrous gas and ether; but Thenard has shown, that it is much more complicated in its

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* Mem. d'Arcueil, i. 360.

nature. The result of his examination is, that it consists chiefly of nitrous oxide gas, mixed with a little nitrous gas, azote, carbonic acid, acetic acid, nitrous acid, and a considerable proportion of ethereal vapour. But the proportion of this last ingredient diminishes according to the degree of cold to which it has been subjected.

And residue examined.

After the mixture of alcohol and nitric acid has ceased to give out ether, there remains in the retort about three-fifths of the original quantity. This residue Thenard also subjected to examination. It has a yellow colour and an acid taste. It consists chiefly of water, holding in solution some nitric acid, some alcohol, a very small portion of acetic acid, and a matter which Thenard could not separate, but which very readily assumed the state of charcoal.

Thus it appears, that both the alcohol and acid are decomposed during the process of making nitric ether, and that the constituents of both enter into the composition of the ether formed. Some light may be thrown upon the subject by a careful examination of the phenomena which take place during the action of nitric acid on alcohol.

Action of nitric acid on alcohol.

1. When equal parts of alcohol and nitric acid are mixed, a violent effervescence takes place; spontaneously if the acid be concentrated; on the application of heat if the acid be diluted. This effervescence is owing to the emission of the gas, which the Dutch chemists considered as a mixture of ether and nitrous gas, but which Thenard has shown to consist chiefly of nitrous oxide and ether. The Dutch chemists have called it *nitrous etherized gas.*[*]

1. Nitrous etherized gas.

This gas has a disagreeable ethereal odour: it burns with a yellow flame; is completely absorbed by water, alcohol, and the solution of potash; ammonia has no action on it. When fired along with oxygen gas it detonates. Sulphuric, sulphurous, nitric, and muriatic acids, decompose it.

2. Oxalic acid.

2. When one part of alcohol and three parts of nitric acid, of the specific gravity 1·261, are mixed together, and a very moderate heat applied, a great quantity of gas is disengaged, which consists chiefly of nitrous etherized gas and nitrous gas. When only $\frac{1}{7}$ part of the liquid remains in the retort, if it be allowed to cool, a number of crystals of oxalic acid are formed.[†] By this process 1·167 parts of oxalic acid may be obtained from 16 parts of alcohol.[‡]

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[*] Jour. de Phys. xlv. 245.

[†] Scheele and Hermbstadt.

[‡] Sage, Jour. de Phys. l. 316.

Combustion of alcohol.

3. When one part of nitric acid is poured upon its own weight of alcohol, and one part of sulphuric acid is added a little after, the mixture takes fire and burns with great rapidity. When this experiment is performed in close vessels, the products are ether and oil, besides what remains in the vessel in which the combustion takes place.*

Howard's fulminating mercury.

4. When nitric acid, partly saturated with mercury, is poured upon alcohol, and heat applied, the products are nearly the same, but the phenomena are very different. The curious appearances which accompany this mixture were first observed and explained by Mr. Howard.† The process, as described by him, is as follows: dissolve, by means of heat, 100 grains of mercury in a measured ounce and a half of nitric acid, of the specific gravity of about 1·3. Pour this solution upon two measured ounces of alcohol, and apply heat till the mixture begins to effervesce. The heat is then to be withdrawn. The action becomes violent, and continues for some time; a dense white smoke issues from the vessel, which is heavier than the atmospheric air, and may be poured into glass jars, where it continues for some time like fine white clouds. Mr. Howard has made it probable that this fume is composed of etherized nitrous gas holding oxide of mercury in solution. Meanwhile a white powder falls to the bottom of the mixture. When the effervescence is over, this white powder is to be separated by filtration, washed with pure water, and dried in a heat not exceeding 212°.

Mr. Howard has examined the properties of this powder, which has the appearance of minute crystals. He has given it the name of *fulminating mercury*.

When heated to the temperature of 368°, it explodes with considerable violence. The same effect is produced by friction, by the blow of a hammer, by electricity, and by flint and steel. The products, after combustion, are carbonic acid gas, azotic gas, water, and mercury. It produces very violent effects, but only at a small distance. Concentrated sulphuric acid, when poured upon it, causes an immediate explosion; diluted sulphuric acid likewise decomposes it, but without exploding. A gas passes over, which is a mixture of carbonic acid, and of a peculiar inflammable gas which burns with a greenish flame: the same into which the etherized nitric gas

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* Brugnatelli, Ann. de Chim. xxix. 327.

† Nicholson's Journal, iv. 173.

is converted by the action of diluted sulphuric acid. There remains in the sulphuric acid a white powder, consisting of oxalate of mercury and a few globules of mercury.*

Composition.

From the experiments of Mr. Howard, it follows that this powder is composed of oxalate of mercury and nitrous etherized gas. But the subsequent analysis of Fourcroy has shown, that it varies in its nature according to the mode of preparing it. When prepared in Howard's way with little heat, it is a compound of nitric acid, oxide of mercury, and a peculiar vegetable substance. When the heat is continued during the whole fermentation, the powder has a greenish colour. It detonates more feebly, and on hot coals emits a blue flame. It is composed in that case of ammonia, oxide of mercury, and more of the peculiar vegetable matter. When the mixture is boiled for half an hour, the powder is composed of oxalate of mercury and a very small quantity of vegetable matter. It does not detonate, but decrepitates when heated.† These experiments of Fourcroy enable us to reconcile the seemingly opposite results of Howard and Berthollet.‡

SECT. III.

OF CHLORIC ETHER §.

I GIVE this name to the compound formed by the union of equal volumes of chlorine and olefiant gas. It has been already described in the first volume of this work.|| It is composed of 1 atom olefiant gas, and 1 atom of chlorine; so that its constitution is as follows:

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* Howard, Nicholson's Journal. iv. 173. Brugnatelli has announced, that by pouring one ounce of alcohol and one ounce of nitric acid on 100 grains of dry nitrate of silver, (lunar caustic,) in a beer glass, a fulminating silver is produced, much more powerful than fulminating mercury. Nicholson's Jour. vii. 285.

† Journal of the Royal Instit. i. 256.

‡ According to Berthollet, fulminating mercury is composed of ammonia, oxide of mercury, and altered alcohol, which produces carbonic acid when decomposed. Phil. Mag. xii. 92.

§ I have some suspicion that this compound should rather be considered as a species of alcohol than of ether. But in the present state of our knowledge I did not venture to adopt that arrangement. But I have no doubt that hereafter different species of alcohol will be recognized as well as of ether.

|| See vol. i. p. 237.

2 atoms hydrogen = 0·25
2 atoms carbon = 1·50
1 atom chlorine = 4·5

6·25

I have little doubt that the ether made by distilling a mixture of alcohol and different chlorides, as the perchloride of mercury, the chlorides of iron, arsenic, and antimony, and especially the fuming liquor of Libavius is, in reality, chloric ether. By means of this chloride, Courtanvaux formed ether, in 1759, by the following process: three parts of fuming muriate of tin and one part of alcohol are mixed together; and after the vapours and heat produced have subsided, the mixture is put into a retort, to which two large receivers are attached, and distilled. There comes over first a little alcohol, then the ether.* This chloride has been recommended as very proper for making ether by Klaproth.†

SECT. IV.

OF MURIATIC ETHER.

After the discovery of sulphuric and nitric ethers, various attempts were made to obtain ether by the action of muriatic acid on alcohol: but this acid in its usual state is too much diluted with water to act with much energy upon alcohol. It was thought necessary, therefore, in order to procure muriatic ether, to employ the acid in a different state. The method of obtaining this ether is as follows:

Preparation.

Pure alcohol is saturated with muriatic acid gas as free from water as possible. The following is the formula recommended by Mr. Basse. Keep a quantity of common salt for an hour in a state of fusion, in order to deprive it of its water of crystallization. Put 20 parts of this salt into a tubulated retort, to the beak of which is fitted a bent tube, plunging into Woulfe's bottle, containing 10 parts of alcohol as strong as possible.

Introduce into the retort, in small quantities at a time, 10 parts of the most concentrated sulphuric acid, allowing the

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* Jour. de Scav. 1759, p. 549. This process was discovered by Rouelle. See Jour. de Phys. lvi. 219.

† Crell's Annals, 1796, ii. 99.

common air to escape from the bottle containing the alcohol; then distil in a sand bath till the muriatic acid comes over, keeping the alcohol bottle as cool as possible during the process. The alcohol, thus saturated with acid, is put into a retort, and one half of it distilled over. Agitate this portion with an alkaline ley, and then decant off the ether which swims on the surface: it usually amounts to $2\frac{1}{2}$ parts.*

Very little was known of the properties of muriatic ether, till Gehlen published a dissertation on the subject in 1804.† He employed two processes: 1. the action of the fuming liquor of Libavius on alcohol; 2. the process of Basse detailed above. Both of them furnished ether, the peculiar properties of which he has described with accuracy. Thenard published three dissertations on it in 1807,‡ pointed out the simplest process for obtaining it, examined the effect of chlorides on alcohol, described the properties of muriatic ether in detail, and made a set of experiments to ascertain its constituents. To the dissertations of these two chemists we are indebted for all that we know of this very remarkable substance.

Thenard's process.

The process recommended by Thenard for procuring this ether is the following: Equal bulks of muriatic acid and alcohol, both as strong as possible, are put into a retort, of such a size as not much more than to hold the mixture. A few grains of sand should be put into the retort, to prevent the violent boiling which might otherwise take place. From the beak of the retort a tube passes into a glass jar, twice the size of the retort, and furnished with three mouths. This jar should be half filled with water, of the temperature of about 70°. Into the second mouth a straight tube of safety is luted, and into the third a tube, which passes into a water trough to receive the gas. When heat is applied, the mixture soon emits bubbles. There passes into the receiver alcohol with acid and water: but the whole of the ether makes its escape in the state of gas, and must be received in proper vessels. From 500 grammes of acid and the same bulk of alcohol, between 20 and 30 litres of ethereal gas are obtained. Or, in round numbers, a mixture of acid and alcohol, weighing about 30 ounces troy, will yield between 1220 and 1830 cubic inches of ethereal gas.

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* Jour. de Chim. ix. 86.

† Gehlen's Jour. ii. 206.

‡ Mem. d'Arcueil, i. 115, 140, 337.

This gas is colourless, it has a strong ethereal smell, and a sweetish taste. It produces no change on the infusion of litmus, the syrup of violets, or lime water. Its specific gravity is 2·219, that of air being 1. At the temperature of 64° water dissolves its own bulk of this gas.

Properties of the ether.

When exposed to a cold of 52°, it loses its aërial form and becomes liquid ether. It may be procured abundantly in that state by passing it into a dry glass jar surrounded with ice. Muriatic ether, in its liquid state, is colourless like water, very liquid, has no action on vegetable blues, and has the same smell and taste as in the gaseous state. At the temperature of 41°, Thenard found it of the specific gravity 0·874.* It is much more volatile than alcohol, or even sulphuric ether, assuming the gaseous state when not hotter than 64°. None of the usual tests indicate the presence of any muriatic acid. It does not affect vegetable blues, nor give out acid when agitated with an alkaline ley, or occasion an immediate precipitate when mixed with nitrate of silver. But when brought in contact with a combustible it burns readily with a green coloured flame, and a very considerable portion of muriatic acid is immediately disengaged in the state of vapour. This very extraordinary fact was first observed by Gehlen: it has been minutely examined by Thenard. When allowed to remain for a long time in contact with an alkali, it does give out a portion of muriatic acid, and it slowly produces a precipitate in nitrate of silver after the interval of several days, and the quantity of precipitate increases with the time. But in neither case is the ether decomposed, or deprived of the property of giving out muriatic acid when burnt.

Composition.

Thenard has endeavoured to ascertain the composition of muriatic ether. From the quantity of muriatic acid which disappears during its formation, he has calculated that 100 parts of muriatic ether contain 29·44 of acid; an enormous quantity, since it exceeds the proportion of real acid in the strongest muriatic acid of commerce. By mixing determinate portions of muriatic ether gas with oxygen gas, firing the mixture, and ascertaining the products, which are only carbonic acid and water, he endeavoured to ascertain the pro-

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* Basse obtained it of the specific gravity 0·820, and Gehlen of 0·845. Here we must consider weight as a mark of purity. Hence it is obvious that the muriatic ether of the German chemists was less pure than Thenard's.

portion of the other constituents. The following is the result of his examination:

29·44	muriatic acid
36·61	carbon
23·31	oxygen
10·64	hydrogen
100·00 [*]	

I have very little doubt that this ether is a compound of 1 volume of olefiant gas + 1 volume muriatic acid gas condensed into 1 volume. On this supposition, the specific gravity will be that of olefiant gas and that of muriatic acid gas added together. Now, the specific gravity of these bodies is as follows:

Olefiant gas	0·974
Muriatic acid gas ...	1·284
	2·258

But 2·258 agrees very nearly with 2·219, the specific gravity of muriatic ether gas obtained experimentally by Thenard. If this supposition be well founded, muriatic ether must be a compound of 2 atoms olefiant gas and 1 atom muriatic acid, so that its constitution will be as follows:

5 Atoms hydrogen = 0·625
4 Atoms carbon = 3·000
1 Atom chlorine = 4·5
8·125

It is composed of 10 atoms, and its weight 8·125.

SECT. V.

OF HYDRIODIC ETHER.

This ether was discovered by M. Gay-Lussac. He formed it by mixing together 2 volumes of absolute alcohol and 1 volume of hydriodic acid, of the specific gravity 1·7, and distilling in a water-bath. He obtained an alcoholic liquid perfectly neutral, colourless, and limpid. When mixed with water, a liquid precipitated in small globules, at first milky, but which

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[*] Mem. d'Arcueil, i. 311.

gradually became transparent. This liquid was hydriodic ether. What remained in the retort was hydriodic acid, much coloured by an excess of iodine.

Properties.

Hydriodic ether, after being well washed with water, is perfectly neutral. Its odour is strong, and, though peculiar, it is analogous to that of other ethers. In a few days it acquires a reddish colour, which does not increase in intensity. Mercury and potash instantly destroy this colour by removing the iodine to which it is owing. Its specific gravity, at 72°, is 1·9206. It boils at the temperature of $148\frac{1}{2}$°. It is not inflammable, but merely gives out purple vapours when put upon burning coals. Potassium may be kept in it without alteration. Potash does not alter it immediately, neither do nitric, and sulphurous acids, or chlorine. Sulphuric acid renders it instantly brown. When passed through a red-hot tube, it is decomposed, an inflammable carburetted gas is obtained, hydriodic acid evolved, and some charcoal deposited.*

This ether has not been analyzed; but we may consider it from analogy as a compound of 2 atoms olefiant gas and 1 atom hydriodic acid. On this supposition its constitution will be

5 Atoms hydrogen. . . = 0·625
4 Atoms carbon .... = 3·000
1 Atom iodine ...... = 15·625
19·250

So that it will be a compound of 10 atoms, and its weight will be 19·25.

SECT. VI.

OF ACETIC ETHER.

Ether may be produced also by the action of acetic acid on alcohol. This was discovered by the Count de Lauraguais in 1759.† He obtained it by distilling a mixture of acetic acid and alcohol with the same precautions as are employed in the distillation of sulphuric ether.

Preparation.

The process, as corrected by Pelletier, is as follows: Mix together, in a retort, equal quantities of acetic acid (from acetate of copper) and alcohol, and distil over the alcohol. Pour it back into the retort, and distil a second time. What comes

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* Ann. de Chim. xci. 89.

† Jour. de Scav. 1759, p. 324.

over must be poured back a second time, and subjected to a third distillation. The product of this third distillation is a mixture of acetic acid and ether. Saturate the acid with potash, and distil with a moderate heat. Acetic ether comes over pure.[*] Bucholz has given another process, which is much more economical. Put into a retort 16 parts of acetate of lead, 6 parts of strong sulphuric acid, and 9 parts of alcohol. Distil over 10 parts. Agitate this liquid with a third of its bulk of lime-water, and decant off the ether, which will swim on the surface. It usually amounts to six parts.[†]

Scheele process.

Scheele could not succeed in obtaining ether by Lauraguais' process; most likely because he neglected to return the distilled liquid a sufficient number of times into the retort. But he discovered another, by which it may be obtained without difficulty. Nothing more is necessary than to add a little sulphuric acid to the mixture; or acetic ether may be obtained by dissolving one part of acetate of potash in three parts alcohol, adding more sulphuric acid than is sufficient to saturate the potash, and then distilling.[‡]

Schulz, an apothecary at Kiel, repeated the experiments of Scheele, and found them accurate. His experiments were repeated by Gehlen and Lichtenberg with the same result. They affirm that pure acetic acid does not form ether with alcohol, but that ether is formed if there be present the smallest quantity of any other acid.[§] The subject has been lately examined by Henry[||] and by Thenard;[**] both of whom have shown in the most satisfactory manner, that acetic acid and alcohol yield an ether by the process of Lauraguais and Pelletier.

Thenard employed nearly equal weights of a very strong acid and alcohol of the specific gravity 0·8056, and repeated the distillation 12 times. No gas of any kind was evolved during the process. He then mixed the whole together, and endeavoured to neutralize the acetic acid by potash. The neutrallization succeeded but imperfectly; abundance of crystals of acetate of potash precipitated. By a cautious distillation the acetic ether came over in the first place, and afterwards a portion of alcohol, holding a little ether and acetic acid in solution. By a subsequent distillation off acetate of potash, the acetic ether was obtained perfectly pure. During the forma-

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[*] Jour. de Phys. xxviii. 141.

[†] Jour. de Chim. iii. 222.

[‡] Scheele, ii. 117.

[§] Ann. de Chim. lvii. 94.

[||] Ann. de Chim. lviii. 199.

[**] Mem. D'Arcueil, i. 153.

tion of this ether, a quantity of acid as well as of alcohol disappear; both of course enter into the composition of the ether, or at least their constituents enter.

Properties.

Acetic ether is limpid and colourless; it has an agreeable odour of ether and acetic acid. It does not redden vegetable blues. It has a peculiar taste, different from that of all other substances, and bearing no resemblance to that of alcohol. Its specific gravity at the temperature of 44½° is 0·866. It boils at the temperature of 160°. It burns with a yellowish-white flame, and acetic acid is developed during its combustion. It does not undergo any change by keeping. At the temperature of 62° it requires more than seven times its weight of water to dissolve it.

Though allowed to remain in contact with water, or dissolved in it, no change takes place; but when left in contact with caustic potash, acetic acid is gradually evolved, which saturates the alkali. If it be distilled in this state, alcohol comes over very much diluted with water. No gaseous matter is disengaged. Hence it seems to be nothing else than a compound of acetic acid and alcohol. The acid is neutralized in the ether, as it exhibits none of its usual properties.

I am disposed to consider acetic ether as a compound of 2 atoms of olefiant gas and 1 atom of acetic acid. On that supposition its constituents will be

7 Atoms hydrogen .... = 0·875
8 Atoms carbon ...... = 6·
3 Atoms oxygen ...... = 3·
9·875

So that its weight is 9·875, and it is a compound of no fewer than 18 atoms.

SECT. VII.

OF FORMIC ETHER.

This ether was first formed by Gehlen. It may be prepared precisely in the same way as acetic ether, merely substituting the formic acid for the acetic.

Properties.

When pure, it has an agreeable odour, very similar to that of peach kernels. Its taste is likewise similar, leaving an impression of ants. Its specific gravity, at the temperature of

63°, is 0·9157. It burns with a blue flame, edged with yellow, and at the temperature of 63° is soluble in nine times its weight of water.* This ether has not been analyzed, but if we consider it from analogy as a compound of 2 atoms olefiant gas and 1 atom formic acid its constitution will be as follows:

5 Atoms hydrogen .... = 0·625
6 Atoms carbon ...... = 4·5
3 Atoms oxygen ...... = 3·

8·125

So that its weight is 8·125, and it contains 14 atoms of simple bodies.

Scheele could not succeed in his attempts to form ether by means of the following acids:

1. Muriatic.
2. Fluoric.
3. Boracic.
4. Benzoic.
5. Tartaric.
6. Citric.
7. Succinic.
8. Arsenic.

But we have seen that an ether may be formed by means of the first and last of these acids. It would seem that before an acid be capable of forming ether, it must be volatile and have a strong affinity for water.

CHAP. III.

OF VOLATILE OILS.

The term *oil* is applied to a number of unctuous liquids, which, when dropped upon paper, sink into it, and make it seem semitransparent, or give it what is called a *greasy* stain. These bodies are very numerous, and have been in common use from time immemorial. Chemists have divided them into two classes; namely, *volatile* and *fixed* oils. We shall consider the properties of the first of these classes in this chapter. The *fixed* oils will occupy our attention in the next. A third class of oils might be added which possess intermediate properties between the fixed and the volatile.

Volatile oils, called also *essential oils*, are distinguished by the following properties:

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* Schweigger's Journal, iv. 1.

Characters.

1. Liquid; often almost as liquid as water; sometimes viscid.
2. Very combustible.
3. An acrid taste and a strong fragrant odour.
4. Volatilized at a temperature not higher than 212°.
5. Soluble in alcohol, and imperfectly in water.
6. Evaporate without leaving any stain on paper.

By this last test it is easy to discover whether they have been adulterated with any of the fixed oils. Let a drop of the volatile oil fall upon a sheet of writing paper, and then apply a gentle heat to it. If it evaporates without leaving any stain upon the paper, the oil is pure; but if it leaves a stain, it has been contaminated with some fixed oil or other.

Preparation.

Volatile oils are almost all obtained from vegetables, and they exist in every part of plants; the root, the bark, the wood, the leaves, the flower, and even the fruit, though they are never found in the substance of the cotyledons; whereas the fixed oils, on the contrary, are almost always contained in these bodies.*

When the volatile oils are contained in great abundance in plants, they are sometimes obtained by simple expression. This is the case with the oil of oranges, of lemons, and of bergamotte; but in general they can only be obtained by distillation. The part of the plant containing the oil is put into a still with a quantity of water, which is distilled off by the application of a moderate heat. The oil comes over along with the water, and swims upon its surface in the receiver. By this process are obtained the oil of peppermint, thyme, lavender, and a great many others, which are prepared and employed by the perfumer. Others are procured by the distillation of resinous bodies. This is the case in particular with oil of turpentine, which is obtained by distilling a kind of resinous juice, called turpentine, that exudes from the juniper.

Properties.

Volatile oils are exceedingly numerous. They have been long known; but as their use in chemistry is but limited, they have not hitherto been subjected to an accurate chemical investigation. They differ greatly in their properties from each other; but it is impossible at present to give a detailed account of each.

Liquidity.

1. The greater number of volatile oils are *liquid*, many indeed are as limpid as water, and have nothing of that appearance which we usually consider as *oily*. This is the case with

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* Fourcroy, vii. 352.

the following; namely, oil of turpentine, oranges, lemons, bergamotte, roses. Others have the oily viscidity. It varies in them in all degrees. This is the case with the oils of mace, cardamom, sassafras, cloves, cinnamon. Others have the property of becoming solid. This is the case with the oils of parsley, fennel, aniseed, balm. Others crystallize by slow evaporation. This is the case with oil of thyme, peppermint, marjoram. The oil of nutmegs has usually the consistence of butter.* This is the case also with the oil of hops and of pepper.

Colour.

2. The colour of the volatile oils is as various as their other properties. A great number are limpid and colourless, as oils of turpentine, lavender, rosemary, savine, aniseed. Some are yellow, as spike, bergamotte. Some are brown, as thyme, savory, wormwood. Others blue, as camomile, motherwort. Others green, as milfoil, pepper, hops, parsley, wormwood, cajeput, juniper, sage, valerian. Others, though at first colourless, become yellow or brown by age, as cloves, cinnamon, sassafras.†

Odour.

3. Their odours are so various as to defy all description. It is sufficient to say, that all the flagrance of the vegetable kingdom resides in the volatile oils. Their taste is always acrid, hot, and exceedingly unpleasant.

Specific gravity.

4. Their specific gravity varies very considerably, not only in different oils, but even in the same oil in different circumstances. The following are the specific gravities of several of the volatile oils, as ascertained by Dr. Lewis.‡

Oil of sassafras	1·094	Oil of Tansy	·946
Cinnamon	1·035	Carraway seeds	·940
Cloves	1·034	Origanum	·940
Fennel	·997	Spike	·936
Dill	·994	Rosemary	·934
Pennyroyal	·978	Juniper berries	·911
Cummin	·975	Oranges	·888
Mint	·975	Turpentine	·792
Nutmegs	·948		

Volatile.

When the volatile oils are heated in the open air, they evaporate readily, and without alteration, diffusing their peculiar odours all around; but there is a considerable difference between the different oils in this respect. When distilled in close vessels, they do not so readily assume the form of va-

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* Fourcroy, vii. 505. Eng. Trans.

† Neuman's Chem. p. 272.

‡ Ibid.

pour. Hence they lose their odour, become darker in colour, and are partly decomposed. Oils do not seem very susceptible of assuming the gaseous form, unless some other substance, as water, be present.

When exposed to the action of cold, they congeal like the fixed oils; but the temperature necessary to produce this effect varies according to the oil. Some of them, as oil of anise and of fennel, become solid at the temperature of 50°: frozen oil of bergamotte and of canella become liquid at 23°; oil of turpentine at 14°.* Margueron exposed several volatile oils to a cold of −17°. They congealed or rather crystallized partially, and at the same time emitted an elastic fluid. These crystals consisted partly of the oils themselves, partly of other substances. Some of them had the properties of benzoic acid.†

Changed by light.

5. Volatile oils, when exposed to the action of light in close vessels, and excluded from common air, undergo very singular changes. Their colour becomes deeper, they acquire a great deal of consistency, and their specific gravity is considerably increased. The cause of these changes is but imperfectly known. Tingry, to whom we are indebted for these interesting researches, has proved that light is a necessary agent. It was supposed formerly that they were occasioned by the absorption of oxygen; and when oxygen is present, it has been ascertained that it is absorbed: but Tingry has proved that the same changes go on when oxygen is excluded. This philosopher ascribes them to the fixation of light. If this be the real cause, the quantity of light fixed must be enormous; for as the specific gravity of the oils is increased considerably while the bulk continues the same, it is evident that the absolute weight must be increased proportionably. One circumstance, however, renders this conclusion somewhat doubtful, at least in its full extent; and that is, that the quantity of change was always proportional to the quantity of the oil and the quantity of air contained in the vessel.‡

II. It is probable that the volatile oils absorb and combine with the different supporters of combustion, though no correct set of experiments has been hitherto made on the subject.

Absorb oxygen.

1. When volatile oils are exposed to the open air, they gradually become deeper coloured, and acquire more and more viscidity, while at the same time their odour diminishes. Dr.

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* Margueron, Jour. de Phys. xlv. 136.

† Ibid.

‡ Tingry, Jour. de Phys. xlvi. 161 and 249.

Priestley first ascertained that they imbibe oxygen with rapidity, and that the changes are owing to this absorption. He tried the experiment only with oil of turpentine, but he found that the air above oils of mint and cinnamon, confined in phials half full, was deprived of its oxygen.* He ascertained likewise, that, independent of this disposition to absorb oxygen, oil of turpentine has the property of imbibing a considerable quantity of air, which may be afterwards extricated by means of the air-pump.† According to Fourcroy, this absorption of oxygen is accompanied by the formation of water. His evidence for this is, that drops of water, he says, are often perceptible at the *surface* of those oils that are kept in vessels not properly closed.‡ By long exposure the volatile oils assume the form of resins.

When the volatile oils are heated sufficiently in the open air, they take fire and burn with a clear bright flame, emitting a vast quantity of smoke. The products of the combustion, besides the soot, are water and carbonic acid.

2. Oil of turpentine at least absorbs and combines with chlorine, and the properties of the new compound are very different from those of oil of turpentine. Mr. Porrett caused the vapour of oil of turpentine and chlorine gas to pass together through a glass tube into a receiver. There was formed a very thick heavy white oil, which sank immediately in water, and which smelt and tasted very much like nutmegs, but communicated rather a more caustic sensation to the tongue.§ A similar compound seems to have been obtained by Dr. John Davy by mixing perchloride of tin with oil of turpentine.||

3. The action of iodine on volatile oils has not been tried.

Action of simple combustibles.

III. The action of the simple combustibles upon the volatile oils is not remarkable. They do not absorb hydrogen as far as is known, neither are they altered by charcoal. When digested upon sulphur at the temperature at which the sulphur melts, they dissolve a portion of it, acquire a brown colour, and a disagreeable taste and smell. These preparations are called *balsams* of sulphur. A portion of the sulphur crystallizes as they cool.** When these balsams are heated strongly, a vast quantity of gas (probably sulphuretted hydrogen) is

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* Priestley on Air, ii 232.

† Ibid.

‡ Fourcroy, vii. p. 501. Eng. Trans.

§ Nicholson's Journal, xxxiii. 195.

|| Ibid. p. 17.

** Elemens de Chymie of the Dijon Academy, iii. 357.

evolved so rapidly as to occasion very violent explosions, unless proper precautions be taken.*

The volatile oils dissolve likewise a portion of phosphorus in a digesting heat; but most of them deposite the whole of it again as the solution cools. Hoffman pointed out a method of rendering the solution permanent. It was the following: Triturate together 10 parts of camphor and 1 of phosphorus. This mixture dissolves readily in most volatile oils, as in oil of cloves, and forms a solution which has the property of rendering every thing luminous which is rubbed with it, and this without combustion.† This seems to have been the solution so much used by Boyle, under the name of *liquid phosphorus*.

Of alkalies and earths.

IV. The alkalies and earths act but feebly upon the volatile oils. The French chemists have proposed to give the combinations which these bodies form with the volatile oils the name of *savonules*, which Dr. Pearson has translated by the term *saponules;* but these denominations have not been adopted by chemists.‡

Whoever considers the tedious trituration of potash and oil of turpentine together, by which the medicinal preparation called *Starkey's soap* is prepared, and compares it with the facility with which that alkali dissolves common turpentine, will be inclined to believe that the combination takes place only in so far as the oil is converted into a resin; and that it is not the oil which has the property of uniting with potash, but the resin formed by its absorbing oxygen from the atmosphere. Indeed it is not improbable, that the volatile oils absorb and part with oxygen, with much greater facility than has been hitherto supposed; and that during many of their solutions these changes take place. Volatile oils seem to unite to alkalies and earths only when united to oxygen so as to form resins; while resins, on the other hand, may probably owe their solubility in alcohol to their parting with oxygen, and assuming the state of volatile oils. Some recent experiments of Mr. Hatchett at least render the last supposition not improbable. I shall mention one: He took about half a pound of the common yellow resin of the shops, and having dissolved it in rather less than

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* Hoffman relates a remarkable story of the violent effects of such an explosion by way of caution to the chemists of his time.—Observationes Phys. Chem. p. 308.

† Hoffman, Observ. Phys. Chem. p. 307.

‡ The term *saponule* does not agree well with the idiom of our language. The word *subsoap*, or something similar, would have been better.

a quart of alcohol, he poured the clear solution from the dregs and impurities into a glass basin containing about two quarts of distilled water. He placed this basin on a sand-bath, and heated it moderately for about four hours. The principal part of the resin was precipitated during this digestion. Next day the milky liquor was poured off the precipitate, and evaporated to dryness in an open vessel. During the evaporation, brittle films of perfect resin were formed successively on the surface of the liquor, and the dry residue, after evaporation, was likewise complete resin; but the portion which had precipitated in the first basin, and which constituted the chief part of the original, was not in the state of resin, but of common turpentine. These phenomena indicate in a very unequivocal manner, that oxygen had been taken from the resin during its solution in alcohol. Hence the portion which precipitated immediately when the solution was poured into water, not being in contact with the air, fell down in the state of turpentine; while the portion that continued in contact with air became perfect resin.

Oleo-saccharum.

V. When agitated with water, the greater number of the volatile oils render it milky, and communicate to it their peculiar odour. Several of them when dropped upon sugar, if the sugar be afterwards dissolved in water, form a permanent solution, to which the name of *oleo-saccharum* has been given. Margueron has shown that this property belongs only to the purest and most limpid part of the oils.

Action of alcohol, ether, fixed oils.

They are all soluble in alcohol, ether, and fixed oils; though they vary considerably in the facility with which they unite to alcohol. Oil of turpentine, for instance, is known to unite slowly with that liquid. When 1 part of that oil is dissolved in 7 parts of alcohol, the oil separates by degrees, and sinks to the bottom.*

VI. The action of the acids upon the volatile oils has been but imperfectly examined.

Sulphuric acid acts upon them with considerable energy: dissolving them, converting them at first to a substance of a resinous nature, and at last reducing them to the state of charcoal. Hence we may procure the oil in very different states, by separating it from the acid at the end of a longer or shorter interval by pouring the mixture into water. When a volatile oil is dropped very slowly into four times its weight of sulphuric acid, triturating constantly after every addition, a so-

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* Neuman's Chem. p. 288.

lution is formed of a brownish colour. If this solution is poured into 3 or 4 parts of water, and then gently heated, a brown mass separates, which was formerly known by the name of an *acid soap.* Achard is the only chemist who has examined these combinations with attention. His experiments were made chiefly on oil of turpentine. The mass which separates when this oil and sulphuric acid are treated as above described, is of the consistence of soft wax, soluble in water and alcohol; and when decomposed by an alkali, the oily matter which separates unites readily with alkalies.[*] Hence it appears that it has approached the state of a resin.

Muriatic acid has much less action on them than the sulphuric. From Achard's trials it dissolved $\frac{1}{120}$th of its weight of the oil of sassafras. The portion dissolved is probably altered.[†] With muriatic acid oil of turpentine combines and forms a compound very similar in its appearance to camphor.

When nitric acid is thrown upon them suddenly, and in a concentrated state, it acts with such energy as to set them on fire; but when sufficiently diluted with water it dissolves them, and converts them into a yellow substance similar to resin. Chlorine acts in the same way, though with less energy.

Action on metals.

VII. The action of the volatile oils on metals has not been examined with care, but it cannot be remarkable. Margueron has tried the effect of some of the salts of mercury upon several volatile oils. The following are the facts ascertained by this chemist: When oil of rosemary is kept over nitrate of mercury, the salt is gradually decomposed, and the oil acquires a deep colour. Corrosive sublimate, in like manner, deepens the colour and increases the consistence of oils of citron, chevril, hyssop, lavender, rosemary, and peppermint; while it is at the same time partly converted into calomel. Neither the muriate of mercury, nor the sulphuret of that metal, produce any change in the oils of lavender and rosemary: but by this last oil the red oxide of mercury is converted into the black, though the oil does not experience any sensible change. The chloride of antimony is likewise decomposed by the oil of rosemary.[‡]

VIII. From the effects of the acid supporters on the volatile oils, and from the products which they yield when burnt, it has been concluded that they are composed of hydrogen and

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[*] Jour. de Phys. xvi. 409.

[†] Elemens de Chymie of the Dijon Academy, iii. 361.

[‡] Ann. de Chim. xlvii. 66.

carbon, sometimes united with various proportions of oxygen according to circumstances: but no exact analysis has yet been made of any of them.

IX. Volatile oils are applied to a great number of uses: Some of them are employed in medicine; some of them, as oil of turpentine, are much used to dissolve resins, which are afterwards employed as varnishes. Not to mention their employment in painting and in perfumery.

CHAP. IV.

OF FIXED OILS.

The fixed oils being very numerous, it has not hitherto been possible for chemists to examine each of them minutely. But Chevreul has been employed for the last eight years in a very laborious investigation of those animal fixed oils, which are capable of being converted into soap; and he has found three distinctly characterized bodies which he has described with precision, and distinguished by the following names.

1. Steärin. 2. Elaïn. 3. Spermaceti.

When these bodies are acted on by salifiable bases they are converted into three substances which possess acid properties, and which by their union with soda constitute hard soap. These acid bodies he calls

Margaric acid. Oleïc acid. Cetic acid.

It is necessary to explain the properties of all these bodies in the present chapter, because without a knowledge of them it would be impossible to understand the nature of *soaps*, or to form a theory of *saponification*. I shall therefore divide this chapter into seven sections. In the first section I shall give a general idea of the properties which characterize the fixed oils, and in the remaining six sections describe the six substances which have been investigated and characterized by Chevreul.

SECT. I.

OF THE FIXED OILS IN GENERAL.

History.

The fixed oils, which are of such extensive utility in the arts, were known at a very remote period. They are mentioned in Genesis, and during the time of Abraham were even used in lamps.* The olive was very early cultivated, and oil extracted from it, in Egypt. Cecrops brought it from Sais, a town in Lower Egypt, where it had been cultivated from time immemorial, and taught the Athenians to extract oil from it. In this manner the use of oil became known in Europe.† But the Greeks seem to have been ignorant of the method of procuring light by means of lamps till after the siege of Troy; at least Homer never mentions them, and constantly describes his heroes as lighted by torches of wood.

Characters.

Fixed oils are distinguished by the following characters:

1. Liquid, or easily become so when exposed to a gentle heat.
2. An unctuous feel.
3. Very combustible.
4. A mild taste.
5. Boiling point not under 600°.
6. Insoluble in water and nearly so in alcohol.
7. Leave a greasy stain upon paper.

Preparation.

These oils, which are also called *fat* or *expressed* oils, are numerous, and are obtained, partly from animals and partly from vegetables, by simple expression. As instances, may be mentioned whale oil or train oil, obtained from the blubber of the whale and from cod; olive oil, obtained from the fruit of the olive; linseed oil and almond oil, obtained from linseed and almond kernels. Fixed oils may also be extracted from poppy-seeds, hemp-seeds, beech-mast, and many other vegetable substances.

It deserves attention, that the only part of vegetables in which fixed oils are found is the seeds of bicotyledonous plants.‡ In animals they are most usually deposited in the liver, though they are found also in the eggs of fowls.

All these oils differ from each other in several particulars, but they also possess many particulars in common.

1. Fixed oil is usually a liquid with a certain degree of viscidity, adhering to the sides of the glass vessels in which it is contained, and forming streaks. It is never perfectly transparent, having always a certain degree of colour; most usually it is yellowish or greenish. Its taste is sweet, or nearly insipid. When fresh it has little or no smell.

There exist also in the vegetable kingdom a considerable number of bodies, which, at the ordinary temperature of the

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[*] Gen. xv. 17.

[†] Herodot. lib. ii. 59 and 62.

[‡] Fourcroy, vii. 319.

atmosphere are solid, and have hitherto been considered as fixed oils. Palm oil may be mentioned as an example, which has been subjected to a chemical examination by Dr. Bostock.[*] The various substances used in India and Africa as substitutes for butter, and as unguents, may likewise be mentioned. Most of them are obtained from the seeds of trees; different species of the *bassia*, as the *butyracea*, *longifolia*, *latifolia*, *obovata*, yield this butyraceous matter. They have been described by Dr. Roxburgh.[†] The shea or butter tree of Africa, described by Park, seems also to be a species of bassia. These substances, from the experiments of Dr. Bostock, appear to differ a little from the liquid fixed oils in their properties, and to approach the nature of wax. Thus they are sensibly soluble in alcohol and ether, and do not combine so readily with alkalies as the fixed oils.

Specific gravity.

2. All the fixed oils hitherto examined are lighter than water: but they differ greatly from one another in specific gravity. The same difference is observable in different samples of the same oil. The following table contains the specific gravity of such oils as have been examined:

Oil of palm[‡]	0·968
Hazel-nuts[‡]	0·941
Poppies[‡]	0·939
Linseed[§]	0·932
Almonds[‡]	0·932
Walnuts[‡]	0·923 to 0·947
Beech-nut[‡]	0·923
Ben[‡]	0·917
Olives[‖]	0·913
Rape-seed[‖]	0·913
Cacao[**]	0·892

Action of heat.

3. Fixed oil does not begin to evaporate till it be heated above the boiling point of water. As the heat increases, a pretty copious vapour may be seen rising from it; but the oil does not begin to boil till it is heated nearly up to the temperature of 600°.[††] At that temperature it may be distilled over; but it is always somewhat altered by the process. Some water

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[*] Nicholson's Jour. xvi. 161.

[†] Ibid. xix. 372.

[‡] Fabroni, Crell's Annals, 1797, ii. 123.

[§] Shaw's Boyle, ii. 346.

[‖] Ibid.

[**] Brisson.

[††] Linseed-oil, according to Morveau, boils at 590°. Ann. de Chim. xc. 122. Whale oil boils at 640°, and may be heated up to 650°. After being distilled over it boils at 410°.

and acetic acid seem to be formed, a little charcoal remains in the retort, and the oil obtained is lighter, more fluid, and has a stronger taste than before. Oil, thus distilled, was formerly distinguished by the name of *philosophical oil.* During the distillation, a great quantity of heavy inflammable air is obtained.

Fixed oil when in the state of vapour, takes fire on the approach of an ignited body, and burns with a yellowish-white flame. It is upon this principle that candles and lamps burn. The tallow or oil is first converted into the state of vapour in the wick; it then takes fire, and supplies a sufficient quantity of heat to convert more oil into vapour; and this process goes on while any oil remains. The wick is necessary to present a sufficiently small quantity of oil at once for the heat to act upon. If the heat were sufficiently great to keep the whole oil at the temperature of 600°, no wick would be necessary, as is obvious from oil catching fire spontaneously when it has been raised to that temperature. When oil is burnt in this manner, either in the open air or in contact with oxygen gas, the only new products obtained are *water* and *carbonic* acid.

When exposed to the action of cold, fixed oils lose their fluidity, and are converted into ice; but this change varies exceedingly in different oils.

Action of air.

4. When fixed oils are exposed to the open air, or to oxygen gas, they undergo different changes according to the nature of the oil. All of them, as far as experiment has gone, have the property of absorbing oxygen; and by uniting with it they become more and more viscid, and terminate at last in a solid state, being apparently saturated with oxygen. Now there are some oils that retain their transparency after they have become solid; while others become opaque, and assume the appearance of *tallow* or *wax.* This circumstance has given occasion to the division of the fixed oils into two classes: Those that remain transparent are called *drying oils,* while those that become opaque are called *fat oils.*

Drying oils.

5. The drying oils are used as the vehicle of paints and varnishes. Linseed, nut, poppy, and hemp-seed oils, belong to this class. These oils, in their natural state, possess the property of drying oils, but imperfectly. To prepare them for the use of the painter and varnish-maker, they are boiled for some time in an iron pot. By this process they are partly decomposed; abundance of watery vapour and of carburetted hydrogen gas is separated from them. They become deeper coloured, and acquire greater consistency. It is common for

some purposes to set them on fire, to allow them to burn for some time, to extinguish them by covering up the vessel in which they are contained, and to continue the boiling till they acquire the proper degree of viscidity. By this process they lose their unctuous quality in a great measure, so as not to leave a greasy stain upon paper, and approach the nature of resins, with this difference, that they do not become brittle, but retain a degree of toughness and ductility, not unlike what in this country is called *wrought rosin*, or shoemaker's rosin. It is common also in preparing the drying oils to boil them with a little litharge. The change which happens to the oils by this process has not been precisely ascertained. Probably they absorb oxygen from the air, and we know that they undergo a partial decomposition. When they burn for some time, their unctuous quality is much more completely destroyed than by any method which has yet been practised. Hence it is followed frequently in preparing the drying oils for varnishes, and always for printer's ink, which requires to be as free as possible from all unctuosity.

Nut-oil has been found preferable to all other oils for printer's ink; though the dark colour which it acquires during boiling renders it not so proper for red ink as for black. Linseed oil is considered as next after nut-oil in this respect. Other oils cannot be employed, because they cannot be sufficiently freed from their unctuosity. Ink made with them would be apt to come off and smear the paper while in the hands of the book-binder, or even to spread beyond the mark of the types, and stain the paper yellow. The process for making printer's ink is as follows:

Printers' ink.

The oil is made to boil in an iron pot only half filled, set on fire, and allowed to burn for half an hour or more, then boiled gently till it acquires the proper consistence. In this state it is called the *varnish*. Two kinds are prepared, a thicker and a thinner. The thicker is of such a consistence that it draws into threads when cold like weak glue. This varnish is afterwards ground with lamp-black in the proportion of two ounces and a half to sixteen ounces of oil. When newly prepared oil is used for making ink, it is said to be necessary to add a little boiled oil of turpentine and a little litharge; but this is said to have the effect of causing the ink to stick so firmly to the types, that it can with difficulty be removed. Old oil does not require this addition.*

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* Lewis, Phil. Com. p. 371.

Oil prepared by the process above described, is still insoluble in alcohol and water, but it unites readily to more oil. It dries into a tough mass like turpentine, and afterwards is scarcely susceptible of uniting with oil. Dr. Lewis found that linseed oil, when thus converted into a thick varnish, lost $\frac{1}{6}$th of its weight; when boiled till it became quite stiff when cold, it lost nearly $\frac{1}{2}$ of its weight.[*] The property which printer's ink has of adhering to moistened paper shows that the oily nature of the body is greatly altered. In some respects it has approached the nature of mucilage, though in others the difference is very great.

Fat oils.

6. The *fat oils*, when exposed to the atmosphere, gradually become thick, opaque, and white, and assume an appearance very much resembling wax or tallow. Olive-oil, oil of sweet almonds, of rape-seed, and of ben, belong to this class.

When oil is poured upon water, so as to form a thin layer on its surface, and is in that manner exposed to the atmosphere, these changes are produced much sooner. Berthollet, who first examined these phenomena with attention, ascribed them to the action of light: but Sennebier observed that no such change was produced on the oil though ever so long exposed to the light, provided atmospherical air was excluded; but that it took place on the admission of oxygen gas, whether the oil was exposed to the light or not.[†] It cannot be doubted, then, that it is owing to the action of oxygen. It is supposed at present to be the consequence of the simple absorption of oxygen and its combination with the fat oils.

Action of simple combustibles.

7. The action of fixed oils upon the simple combustibles is not very remarkable.

Hydrogen, as far as known, does not act upon them. When they are filtered through charcoal power, they are rendered purer; but on account of the great difficulty of separating the charcoal from fixed oils, it cannot be employed with advantage for purifying them.[‡] Black paint is usually nothing else than charcoal in some state or other ground up with a drying oil.

The fixed oils likewise dissolve a small proportion of phosphorus when assisted by heat. The combination succeeds easiest if a mixture of oil, water, and phosphorus be boiled for a little in a glass vessel. These oily phosphurets emit the

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[*] Lewis, Phil. Com. p. 372.

[†] Ann. de Chim. xi. 89.

[‡] Kels, Crell's Annals; iii. 274, Eng. Trans.

odour of phosphuretted hydrogen, and yield, when distilled, a portion of that gas. When rubbed in the open air, or when spread upon the surface of other bodies, they appear luminous, in consequence of the combustion of the phosphorus. When hot oils saturated with phosphorus are allowed to cool, the phosphorus crystallizes in octahedrons, as Pelletier ascertained.

They readily dissolve sulphur when assisted by heat. The solution assumes a reddish colour. When distilled, there comes over a great quantity of sulphuretted hydrogen gas. When the solution is allowed to cool, the sulphur is deposited in crystals. By this process Pelletier obtained sulphur in regular octahedrons.

Of water.

8. The fixed oils are all insoluble in water. When agitated with that liquid, the mixture becomes milky, but the oily particles gradually separate and swim upon the surface. The presence of a mucilaginous substance, as gum arabic, prevents the oil from separating, and occasions, of course, a permanent milkiness. Such mixtures are called *emulsions*. They are often formed by triturating oily seeds, as almonds, with water; the two ingredients necessary to form an emulsion, oil and mucilage, being present in the seed.

Most of the fixed oils are but sparingly soluble in alcohol. Mr. Brande found that very little olive or almond oil was taken up by alcohol of the specific gravity 0·820. Linseed oil is more soluble, and alcohol dissolves any quantity whatever of castor oil. On that account this oil is sometimes employed to adulterate volatile oils of high value, especially oil of cloves.*

In general the fixed oils are somewhat more soluble in sulphuric ether than in alcohol. Four measures of sulphuric ether of the specific gravity 0·7563 were found by Mr. Brande to dissolve 1¼ measure of almond oil, 1½ measure of olive oil, 2⅓ measures of linseed oil, and any quantity whatever of castor oil.†

The fixed oils unite readily with each other, with volatile oils, and likewise with bituminous and resinous substances.

Alkalies.

9. The alkalies unite readily with the fixed oils, and form the important compounds called *soaps*. The fat oils enter into these combinations more readily than the drying oils.

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* Phil. Trans. 1811, p. 264.

† Ibid. Equal volumes of sulphuric ether and castor oil united together has been found a useful external application in rheumatism.

The earths likewise combine with these oily bodies, and form a kind of soap insoluble in water, and are therefore not capable of being applied to the same uses as common soap.

Acids.

10. The combustible acids, as far as is known at present, do not unite with oils; neither has the muriatic acid any remarkable effect. Phosphoric acid, when concentrated, deepens their colour, and gives them a peculiar smell, especially if assisted by heat: a proof that it acts upon them.* The sulphuric acid acts with much greater energy. The oils become immediately black, and assume gradually the properties of bitumen in proportion to the continuance of the action. If the acid be allowed to remain long enough, they are completely decomposed; water is formed, charcoal precipitated, and an acid evolved.† Other products doubtless also make their appearance, though the action of this acid on oils has not yet been examined with sufficient care. Nitric acid acts with still greater energy. When poured suddenly upon the drying oils, it sets them on fire. The same effect is produced upon the fat oils, provided the acid be mixed previously with a portion of the sulphuric. When the nitric acid is sufficiently diluted, it converts the drying oils into a yellow resinous-like mass, and the fat oils to a substance very like tallow. But the action of this acid upon fixed oils has not yet been sufficiently examined.

Acid soaps.

Many attempts have been made by chemists to form permanent compounds of the concentrated acids and oils under the name of *acid soaps.* The only acid which was found to answer was the sulphuric. Achard published a number of experiments on these compounds. They dissolve in water, and lather like common soap; but as they are not in reality permanent compounds, they cannot be used with much prospect of advantage.

Action on metals.

11. The fixed oils act (though feebly) upon some of the metals when the atmospheric air is not excluded. Copper is soon corroded by them, and a dark green solution obtained. The only other metal upon which they are known to act in the same manner is mercury. By triturating mercury with fixed oils, it gradually disappears, and a bluish coloured unguent is formed; consisting, in part at least, of the black oxide of that metal united to the oil. But this experiment scarcely

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* Elemens de Chimie of the Dijon Academy, iii. 142.

† Fourcroy, vii. 330.

succeeds, except with those oils which are in a state approaching to solidity.

But upon the metallic oxides the fixed oils act with greater energy. They dissolve the white oxide of arsenic with great facility, as was shown long ago by Brandt. When boiled with the oxides of mercury, lead, or bismuth, they form very tough solid compounds, called *plasters*.

Rancidity.

12. Fixed oils are liable, by keeping, to undergo a change well known by the name of *rancidity*. They become thick, acquire a brown colour, an acrid taste, and a disagreeable smell. The oil thus altered converts vegetable blues into red, and of course contains an acid. It is believed at present that this change is owing to the alteration of the foreign substances present in oils, or to the action of those foreign bodies upon the oily matter itself. Several of the fixed oils, when newly extracted, let fall on standing a quantity of mucilaginous matter; and from the experiments of Scheele, it appears probable that they always retain less or more of a similar principle. He boiled together one part of litharge, two parts of olive oil, and a little water. When the oil had acquired the consistence of an ointment, it was allowed to cool, and the water decanted off. When this water is evaporated to the consistence of a syrup, it leaves a substance which Scheele termed the *sweet principle of oils*. It does not crystallize, is soluble in water and alcohol, and is converted into oxalic acid by the action of nitric acid. When heated, it is partly decomposed into a brown oil, and partly volatilized unaltered. This substance he obtained also from linseed and rape-seed oil, and from oil of almonds. Even the oil disengaged from soap yielded him a little of it.* Similar impurities were supposed to exist in all fixed oils, and to occasion their rancidity by putrefaction. This rancidity is in some degree diminished by agitation with water, but not completely destroyed. Mr. Dossie has shown that agitation with the fixed alkaline solutions and quicklime answers the purpose sufficiently well in purifying oils for burning in lamps; but that they have the property of coagulating a portion of the oil. This however may be prevented by adding a quantity of strong brine, which occasions the separation of the foreign bodies from the oil.†

Sweet principle of oil.

Composition of oils.

13. When oil is burnt, the only products are carbonic acid and water. When repeatedly distilled, or when passed

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* Scheele's Opusc. ii. 189.

† Nicholson's Jour. v. 5.

through a red hot tube, it appears to be completely converted into water, carbonic acid, and heavy inflammable air. Lavoisier analyzed olive oil by burning it in a vessel filled with oxygen gas. But the art of analysis was too little advanced at that time to put it in the power of this philosopher with all his sagacity to approach very near the truth. Gay-Lussac and Thenard made an analysis of olive oil in 1808, by burning a determinate quantity of it mixed with chlorate of potash and ascertaining the products. They found it a compound of

Hydrogen	13·360
Carbon	77·213
Oxygen	9·427
	100·000*

We have no means at present of determining the equivalent number for olive oil. But the smallest number of atoms which correspond nearly with the preceding composition are the following:

11 atoms hydrogen .. = 1·375
10 atoms carbon ..... = 7·5
1 atom oxygen ..... = 1·
9·875

According to this statement olive oil is a compound of 22 atoms, and its weight is 9·875. Or it may be represented by ten atoms of olefiant gas combined with 1 atom of water. According to these data 100 parts of it by weight would be composed of

Hydrogen	14·025
Carbon	75·949
Oxygen	10·126

Numbers which do not exactly coincide with the analysis of Gay-Lussac and Thenard; but which approach to it pretty closely.

M. Theodore de Saussure has subjected hog's lard to analysis both in its natural state and after it has been saponified. The following are the results which he obtained.†

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* Recherches Physico-chimiques, ii. 320.

† Phil. Trans. 1819, p. 56.

	Hogslard.	Ditto saponified.
Carbon	78·843	75·747
Hydrogen	12·182	11·615
Oxygen	8·502	12·325
Azote	0·473	0·313
	100·000	100·000

Now this, when converted into volumes, becomes

	Hogslard.	Ditto saponified.
Carbon	621·4 volumes.	604·8 volumes.
Hydrogen	575·4	548·6
Oxygen	25·1	36·3
Azote	1·7	1·0

These volumes approach the following

	Hogslard.	Ditto saponified.
Carbon	25 volumes.	25 volumes.
Hydrogen	23	22·5
Oxygen	1	1·5

We may substitute atoms for volumes simply by doubling the number of volumes of oxygen. This shows us that the composition of hogslard is as follows:

25 atoms carbon	= 18·750	or 12·5 atoms carbon	= 9·3750
23 atoms hydrogen	= 2·875	11·5 atoms hydrogen	= 1.4375
2 atoms oxygen	= 2·000	1·0 atom oxygen	= 1·0000
	23·625		11·8125

While the saponified lard contains half an atom of hydrogen less and 1 atom of oxygen more than the hogslard in its natural state. Though these calculations do not, in all probability, give us the true composition of hogslard, yet they are valuable as first approximations.

SECT. II.

OF STEÄRIN.

This substance was first described by Chevreul in 1814.* It was pointed out likewise by Braconnot in 1815, who does not seem aware of what had been previously done by Chevreul, or at least takes no notice of it.†

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* Ann. de Chim. xciv. 129. See also Ann. de Chim. xciv. 74.

† Ann. de Chim. xciii. 225.

Book II. Division I.

Nature of tallow.

It appears from the experiments of Chevreul that tallow and animal fat of every kind is a mixture or combination of two distinct oily substances. The first of these, which is solid at the usual temperature of the air, he has called *steärin*;* to the second, which is liquid at the same temperature, he has the name of *elaïn*.† From the experiments of Braconnot it would appear that the fixed oils of the vegetable kingdom have the same composition.

Steärin, how procured.

Chevreul obtained *steärin* from hogslard by the following process. The lard, purified as completely as possible from foreign matter, was heated in boiling alcohol. When the alcohol cooled it deposited white crystalline needles, which were steärin. This process was repeated till the whole of the lard was dissolved in the alcohol.‡ The steärin thus obtained in crystals was dissolved a second time in alcohol, and allowed to separate in crystals. By this process the whole of the elaïn is not separated from the steärin; though probably the quantity which remains is not considerable.

The method employed by Braconnot was very simple, and seems to show that in fixed oily bodies the steärin and elaïn are not in chemical combination; but merely mechanically mixed with each other. If the oil to be examined was liquid, he exposed it to cold till it congealed. In this congealed state it was subjected to strong pressure between folds of blotting paper. The elaïn was imbibed by the paper, and the steärin remained behind in a solid state. If the oil to be examined was already solid, it was not necessary to expose it to cold. It was simply subjected to pressure between folds of blotting paper.

Properties.

Steärin obtained by these processes is white, brittle, and has somewhat the appearance of wax. It has little or no smell when pure. It is tasteless and produces no change on vegetable blues. Steärin from hogslard becomes liquid when heated to the temperature of 109°. But there is a considerable differ-

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* From στεας, tallow. † From ελαιον, oil.

‡ The process is greatly facilitated by using absolute alcohol. For the solubility of steärin, in alcohol, diminishes at a much greater rate than the strength of that liquid. Chevreul found that boiling alcohol of the sp. gr. 0 7908 dissolved more than its weight of steärin.

Alcohol of the sp. gr. 0·7925 dissolved $\frac{16·07}{100}$.
Alcohol of the sp. gr. 0·805 dissolved $\frac{6·63}{100}$.
Alcohol of the sp. gr. 0 821 dissolved [illegible].

Ann. de Chim. et Phys. ii 361.

ence in the melting point of the steärin from different bodies. This will appear by the following table.*

Steärin from human tallow fuses at	120°
sheep	109
oxen	111
hog	109
duck	109

It is soluble in alcohol, but the steärin from different bodies varies somewhat in its solubility. This will appear by the following table, for the experiments contained in which we are likewise indebted to Chevreul. 100 parts of boiling alcohol of the specific gravity 0·7952 dissolve

21·50 of steärin from man,
16·07 of steärin from the sheep,
15·48 of steärin from the ox,
18·25 of steärin from the sow,
36·00 of steärin from the duck.

When steärin is digested with an alkaline substance the greatest part of it is converted into soap, only a small portion of it becomes the sweet principle of oils, and a still smaller is acetic acid. The following table, likewise drawn up by M. Chevreul, gives the proportion of steärin from different bodies turned into soap by the action of potash, and the proportion that continued soluble:

Proportions saponified.

Steärin of man	Portion saponified	94·9
	Portion soluble	5·1
		100·00
Steärin of the sheep	Saponified	94·6
	Soluble	5·4
		100·0
Steärin of the ox	Saponified	95·1
	Soluble	4·9
		100·0
Steärin of the hog	Saponified	94·65
	Soluble	5·35
		100·00

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* Chevreul; Ann. de Chim. et Phys. ii. 363.

Steärin of the duck	Saponified	94·4
	Soluble	5·6
		100·0

These differences are so small that it is probable they may be rather ascribed to errors in the experiment, than to real differences in the quantities of soap formed.

Steärin usually crystallizes in small needles, and when a quantity of it is melted and allowed to congeal, the surface becomes very uneven.

SECT. III.

OF ELAÏN.

Preparation.

Elaïn may be obtained from the tallow of different animals by Chevreul's process. He dissolves the tallow in alcohol, allows the steärin to crystallize, and then distills off the alcohol from the elaïn. Braconnot's method appears of easier execution, and will probably yield elaïn of greater purity. He procures his steärin by subjecting the tallow to pressure between folds of blotting paper. The paper imbibes the elaïn. To separate it he soaks the paper in water and subjects it to pressure, the elaïn is forced out and may easily be collected and examined.

Properties.

It has very much the appearance of a vegetable oil, and is quite liquid at the temperature of 59°. Sometimes it is colourless and destitute of smell; but most commonly it has both, owing to the presence of foreign bodies from which it is not possible to free it. Chevreul examined particularly elaïn from the tallow of man, the sheep, the ox, the hog, the jaguar, and the duck. The following are the properties of each:

1. *Elaïn of man*—yellow, without smell, of the sp. gravity 0·913.

2. *Elaïn of the sheep*—colourless, a slight smell of mutton, sp. gravity 0·916.

3. *Elaïn of the ox*—colourless, almost without smell, sp. gravity 0·913.

4. *Elaïn of the hog*—colourless, almost without smell, sp. gravity 0·915.

5. *Elaïn of the jaguar*—lemon yellow, having an odour, sp. gravity 0·914.

6. *Elaïn of the goose*—slightly yellow, almost without smell, sp. gravity 0·929.

Solubility in alcohol.

The solubility of these different varieties of elaïn in alcohol of the sp. gravity 0·7952 was as follows:

1. *Elaïn of man*—100 parts dissolved in 81·08 parts of boiling alcohol, the solution began to become opaque at 170°.

2. *Elaïn of the sheep*—100 parts were dissolved by 81·17 of alcohol at the temperature of 167°, the liquor became muddy at 145°.

3. *Elaïn of the ox*—100 parts were dissolved by 81·03 of alcohol at the temperature of 167°, the liquid became muddy at 145°.

4. *Elaïn of the hog*—100 parts were dissolved by 81·08 of alcohol at the temperature of 167°, the liquid became muddy at 143½°.

5. *Elaïn of the jaguar*—100 parts were dissolved by 80·89 of alcohol at the temperature 167°, the liquid became muddy at 140°.

6. *Elaïn of the goose*—100 parts were dissolved by 81·08 of alcohol of the temperature 167°, the liquid became muddy when cooled down to 124°.

When these different varieties of elaïn were digested for a sufficient time with potash lye, by far the greatest part was converted into soap. But the soluble portion, consisting chiefly of the sweet principle of oils, was rather greater than the quantity formed when steärin was saponified in the same way. The following table exhibits the proportions of elaïn saponified and converted into sweet principle, when the experiment was made with the different varieties above specified.

Proportions saponified.

1. Elaïn from the sheep, hog, jaguar, and goose.

Saponified	89
Soluble	11
	100

2. Elaïn of the ox.

Saponified	92·6
Soluble	7·4
	100·0*

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* Chevreul, Ann. de Chim. et Phys. ii. 366.

To give the reader an idea of the proportion of steärin and elaïn in different varieties of fixed oil, animal and vegetable, I shall insert the following table exhibiting the proportions of each, which Braconnot[*] obtained by his experiments:

Butter	Steärin	40
	Elaïn	60
Hogslard	Steärin	38
	Elaïn	62
Beef marrow	Steärin	76
	Elaïn	24
Mutton marrow	Steärin	26
	Elaïn	74
Goose fat	Steärin	32
	Elaïn	68
Duck fat	Steärin	28
	Elaïn	72
Turkey fat	Steärin	26
	Elaïn	74
Olive oil	Steärin	28
	Elaïn	72
Almond oil	Steärin	24
	Elaïn	76
Oil of colsa	Steärin	46
	Elaïn	54

SECT. IV.

OF SPERMACETI.

THIS peculiar oily substance is found in the cranium of the *physeter macrocephalus*, or spermaceti whale. It is obtained also from some other species. At first it is mixed with some liquid oil, which is separated by means of a woollen bag. The last portions are removed by an alkaline ley, and the spermaceti is afterwards purified by fusion. Thus obtained it is a beautiful white substance, usually in small scales, very brittle, has scarcely any taste, and but little smell. It is distinguished from most other fatty bodies by the crystalline appearance which it always assumes. It melts, according to the experiments of Bostock, at the temperature of 112°.[†] When sufficiently heated it may be distilled over without much alteration; but

Properties.

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[*] Ann. de Chim. xciii. 225.

[†] Nicholson's Jour. iv. 134.

when distilled repeatedly it loses its solid form and becomes a liquid oil.[*] From the experiments of Thouvenel and Crell, we learn that by repeated distillation it is partly decomposed, and a brown acid liquid obtained. It is soluble in boiling alcohol, but separates again as the solution cools. One hundred parts of alcohol, of the specific gravity 0·816, dissolve 6·9 parts of it.[†] Ether dissolves it cold, and very rapidly when hot: on cooling the whole concretes into a solid mass.[‡] It dissolves also in hot oil of turpentine, but precipitates again as the liquid cools.[§]

The acids have scarcely any action on it; but it unites though slowly with the pure alkalies, as was shown long ago by Crell, and the fact has been confirmed by Dr. Bostock and M. Chevreul. With hot ammonia it forms an emulsion which is not decomposed by cooling nor by water; but the spermaceti is immediately thrown down by the addition of an acid.[||] It dissolves sulphur, and is dissolved by the fixed oils. When long exposed to the air it becomes yellow and rancid. This substance is employed like wax and tallow for making candles. It is said also, that if bits of caoutchouc be thrown into it while melted, they are dissolved, and form a compound which answers remarkably well for luting vessels.[**]

The soap of spermaceti, according to Chevreul, is composed of

Saponified spermaceti	100
Potash	8·15

The potash does not seem capable of combining in different proportions with the spermaceti. Water has the property of depriving this soap of the greatest part of the alkali. By saponification the properties of the spermaceti are altered. It acquires acid qualities, but still continues to melt at the same temperature as before. Its solubility in alcohol is greatly increased by saponification.[††]

SECT. V.

OF MARGARIC ACID.

Preparation.

THE first account of this substance was published by Chev-

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[*] Neumann.

[†] Chevreul, Ann. de Chim. lv. 11.

[‡] Bostock, Ibid.

[§] Id. Ibid.

[||] Id. Ibid.

[**] Nicholson's 4to. Jour. i. 472.

[††] Chevreul, Ann. de Chim. xcv. p. 15.

reul in 1813. He obtained it by forming a soap by means of hogslard and potash. When this soap was put into water, a portion of it dissolved, and another portion was deposited under the form of small pearl-coloured scales. These scales were composed of potash and margaric acid. They were well washed in water, and then decomposed by digestion in diluted muriatic acid. The potash combined with this acid, and set the margaric acid at liberty, which floated on the surface of the liquid. Being sufficiently washed with water it is in a state of purity. Mr. Chevreul gave this substance, at first, the name of *margarine*, from its lustre being similar to that of mother of pearl.* He afterwards changed it to *margaretic acid*, in consequence of the decidedly acid properties which it possesses.† Margaric acid, thus prepared, possesses the following properties:

Its colour is pearl white. It is tasteless and has a weak smell, somewhat similar to that of white wax. It is lighter than water. It melts when heated to the temperature of 134° into a colourless and limpid liquid which, on cooling, crystallizes into brilliant needles of the finest white colour.

It is insoluble in water, but very soluble in alcohol, 100 parts of alcohol of the specific gravity 0·816 dissolved (at the temperature of 167°,) 180·79 parts of margaric acid. This solution became muddy when cooled down to 106°. When quite cold it became a solid mass, having the shape of the vessel in which it was contained. When the alcohol solution is allowed to crystallize slowly by not being saturated, the margaric acid is deposited in needles united together in the form of stars.

Margaric acid acts with considerable energy upon vegetable blues, reddening litmus almost immediately. It combines readily with potash in two proportions forming a neutral salt or soap which is insoluble in water. The composition of these soaps, according to the analysis of Chevreul, is as follows:

Soaps of.

Submargarate of potash.

Margaric acid	100
Potash	8·80

Margarate of potash.

Margaric acid	100
Potash	17·77

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* From μαργαριτης, a pearl. Ann. de Chim. lxxxviii. 231.

† Ann. de Chim. et Phys. ii. 346.

If we suppose the first of these compounds to consist of 100 parts of margaric acid united with 9 potash, it will follow that the equivalent number for margaric acid is 33·3.[*]

Margaric acid is capable, likewise, of combining with the other salifiable bases, and forming a great variety of salts, or *soaps* as it would be better to term them. The following table exhibits the composition of these soaps as they have been determined by the experiments of Chevreul.

Margarate of soda.

Margaric acid	100	...... 31·44
Soda	12·72	 4

Margarate of barytes.

Margaric acid	100	...... 33·7
Barytes	28·93	...... 9·75

Margarate of strontian.

Margaric acid	100	...... 32·13
Strontian	20·23	...... 6·5

Margarate of lime.

Margaric acid	100	...... 32·77
Lime	11·06	...... 3·625

Margarate of lead.

Margaric acid	100	...... 16·63
Protoxide of lead ..	83·78	 14

The mean of all these numbers gives 32·86 for the weight of an atom of margaric acid. We may therefore consider 33 as approaching very nearly to the true weight.[†]

When margaric acid is distilled it comes over partly undecomposed, and partly in the state of a yellow concrete butyraceous looking substance, possessing different properties from the acid and not capable of combining with potash. Very little gas is formed and very little charcoal remains in the retort.[‡]

It is not improbable that margaric acid is formed from steärin, though this has not been proved in a satisfactory manner. Steärin yields much more margaric acid than elaïn. Chevreul has examined margaric acid from the tallow of man, the sheep, the ox, the jaguar, and the goose, and found its properties nearly the same as those of margaric acid from

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[*] Chevreul, Ann. de Chim. lxxxviii. 231.

[†] Ibid. xciv. 253.

[‡] Ann. de Chim. lxxxviii. 231.

hogslard. The most striking difference was in the fusibility, which amounted to 9 degrees.*

SECT. VI.

OF OLEÏC ACID.

Preparation.

This substance was first obtained by Chevreul from a soap made by digesting hogslard in potash lye. When this soap was put into water a portion was deposited in pearl-coloured scales, it was a margarate of potash. Another portion dissolved in the water. This portion was a combination of oleïc acid and potash. But it still contained a notable portion of margarate of potash. To separate this portion as completely as possible, the soap dissolved in the water was decomposed by means of tartaric acid. The oleïc acid separated was again converted into soap by means of potash, and this soap again dissolved in water. An additional portion of margarate of potash precipitated. By repeating this process two or three times, the oleïc acid was obtained in a state of tolerable purity. Its properties are as follows:

Properties.

It is an oily fluid when pure, destitute of smell and colour. But most commonly it has a rancid odour, and a yellow or brown colour, so as to have the appearance of some kinds of olive oil. Its specific gravity is 0·899. Sometimes it remains liquid till it be cooled down to 35°; but some varieties of it congeal at 43°, or even at higher temperatures. When congealed it crystallizes in needles. It reddens litmus with great energy.

It is insoluble in water, but very soluble in alcohol. Boiling alcohol of the specific gravity 0·816 dissolves any quantity of it whatever. It combines readily with the salifiable bases and forms different species of salt or *soap*, as the compound ought to be called.† The following table exhibits the composition of these different soaps as it has been determined by the experiments of Chevreul.‡

Soaps of.

Oleate of potash.

Oleïc acid	100	36·18
Potash	16·58	6

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[*] Ann. de Chim. et Phys. ii. 357.

[†] Chevreul, Ann. de Chim. xciv. 90.

[‡] Ann. de Chim. xciv. 263.

Oleate of soda.

Oleïc acid	100	39·56
Soda	10·11	4

Oleate of barytes.

Oleïc acid	100	36·15
Barytes	26·97	9·75

Oleate of strontian.

Oleïc acid	100	33·53
Strontian	19·38	6·5

Oleate of lime.

Oleïc acid	100	37·58
Lime	9·64	4·625

Oleate of magnesia.

Oleïc acid	100	33·24
Magnesia	7·52	2·5

Oleate of zinc.

Oleïc acid	100	34·55
Oxide of zinc	14·83	5·125

Oleate of lead.

Oleïc acid	100	12·28
Protoxide of lead	114·81	14

Oleate of copper.

Oleïc acid	100	71·78
Peroxide of copper	13·93	10

The average of the whole of these analyses gives us 35·94 as the equivalent number for oleïc acid. We may, therefore, without any material error, consider its true weight as amounting to 36. So that it probably contains four more atoms of carbon in its composition than margaretic acid.

Chevreul examined oleïc acid obtained by saponification from the tallow of man, the sheep, the ox, the goose, and found its properties the same nearly as that of oleïc acid from hogslard. The soaps which all these varieties of oleïc acid formed may be considered as identic in their composition.*

SECT. VII.

OF CETIC ACID.

Chevreul has given this name to the matter formed by saponifying spermaceti, a substance which he has thought

* Ann. de Chim. et Phys. ii. 353.

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proper to distinguish by the term *cetin*. Cetic acid is obtained when spermaceti saponified, by means of potash, is decomposed by an acid. It may be distinguished by the following properties:

Properties.

It is a white solid substance destitute of taste and smell. It melts when heated to the temperature of about 113°, agreeing, in this respect, with the spermaceti from which it is formed. When melted cetic acid is allowed to congeal, it does not crystallize in plates like spermaceti.

Cetic acid is insoluble in water. Boiling alcohol dissolves more than its weight of it. As the solution cools, brilliant lamellar crystals are deposited, and at last the whole liquid assumes a solid form. This solution reddens litmus, though it acts with less energy than margaric acid. The great solubility of this substance in alcohol, and its action on vegetable blues, distinguish it from spermaceti.

It combines readily with the salifiable bases and forms different species of salts or soaps. The soap or cetate of potash, according to the analysis of Chevreul, is composed of

Cetic acid	100	72·13
Potash	8·29	6

According to this analysis the weight of an atom of cetic acid is double that of an atom of oleïc acid. It is more probable, however, that the soap examined was a bicetate of potash. On that supposition the weight of oleïc and cetic acids would be the same.*

Poisonous oils.

Besides the volatile and fixed oils, there is another set which exist pretty frequently in the vegetable kingdom. Their chemical properties are intermediate between the fixed and the volatile oils. Like the volatile oils they dissolve in alcohol; but like the fixed they cannot be distilled over with that liquid. Hence they may be obtained by digesting the vegetable substance that contains them in alcohol, and then separating the alcohol from the oil by distillation. They have all a strong acrid taste, and most of them possess poisonous qualities. The alcoholic solution of some of them has the property of precipitating sulphate of iron of a reddish colour, which be-

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* Chevreul, Ann. de Chim. xcv. p. 17.

comes green when mixed with an alkaline solution. Vauquelin detected an oil of this nature in the root of the helleborus hyemalis.* A similar oil appears to exist in tobacco and in many other plants.

CHAP. V.

OF BITUMENS.

The term *bitumen* has often been applied by chemists to all the inflammable substances that occur in the earth; but this use of the word is now so far limited, that *sulphur* and *mellite* are most commonly excluded. It would be proper to exclude *amber* likewise, and to apply the term to those fossil bodies only which have a certain resemblance to oily and resinous substances. In this restricted sense the word is used in the present chapter.

Division.

Bituminous substances may be subdivided into two classes: namely, *bituminous oils*, and *bitumens*, properly so called. The first set possess nearly the properties of volatile oils, and ought in strict propriety to be classed with these bodies; but as the chemical properties of bitumens have not yet been investigated with much precision, it was deemed rather premature to separate them from each other. The second set possess properties peculiar to themselves. Let us endeavour to describe the substances belonging to these two classes as far as possible.

SECT. I.

OF BITUMINOUS OILS.

Only two species of bituminous oils have been hitherto examined by chemists. Others indeed have been mentioned, but their existence has not been sufficiently authenticated. These two species are called *petroleum*, and *maltha*, or *sea-wax;* the first is liquid, the second solid.

Petroleum.

1. Petroleum is an oil of a brownish yellow colour. When

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* Ann. de Mus. d'Hist. Nat. No. xliii. 82.

pure, it is fluid as water, and very volatile.* Its specific gravity varies from 0·730 to 0·878.† It has a peculiar smell. When heated, it may be distilled over without alteration.

Petroleum is found in the earth in various states of purity; sometimes without any mixture of foreign substances. In this state it is usually distinguished by the name of *naphtha*, and is said to occur in great abundance on the shores of the Caspian and in Persia. It occurs also in different parts of Europe, especially Italy and Germany. When less fluid and darker coloured, it is commonly called *petroleum*. It is supposed to owe this increased spissitude and deepened colour to the action of the air. When distilled, it yields a quantity of pure petroleum, while a portion of bitumen of the consistence of tar or pitch remains behind. When long exposed to the air, petroleum becomes black, and acquires the semifluidity of tar. In this state the greatest part of it is insoluble in alcohol; so that it has assumed the state of true bitumen.

Petroleum is used in those countries, where it abounds, as an oil for lamps. It is employed also as a solvent of resinous bodies, and of the proper bitumens, which it dissolves with facility.

Naptha.

When petroleum is distilled at a low heat, the liquid which comes first over is distinguished by the name of *naphtha*. It is colourless, perfectly fluid; is very volatile, and has a peculiar smell. Coal tar, or the oily matter which comes over when coal is distilled at a red heat, yields, when repeatedly rectified, the very same kind of liquid. Naphtha is observed also in different places rising spontaneously from the earth nearly in a state of purity. As, for example, in different parts of Persia, at Amiano in Italy, and in many other places. This natural production of naphtha is observed in many places where no coal has been ever discovered. Yet I think it not improbable, from the exact similarity between the properties of natural naphtha and coal naphtha, that they have in reality the same origin.

The specific gravity of naphtha varies considerably, proba-

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* The volatility seems to have been over-rated by older chemical writers. On mixing well rectified petroleum with water in a retort, I found that the water could be readily distilled over in a moderate heat, while the whole petroleum remained behind.

† See Kirwan's Mineralogy, ii. 42.

bly according to its state of purity. The following are the specific gravities which I have myself ascertained.

1	Persian naphtha, not rectified . .	0·753
2	Coal naphtha, perfectly colourless	0·817[*]
3	Coal naphtha, slightly yellow . .	0.850[†]
4	Natural naphtha of Amiano . .	0·836[‡]
5	Ditto, thrice rectified	0·758[‡]

Naphtha is very volatile: a drop of it let fall on paper disappears in a few minutes. Yet its boiling point is rather higher than that of oil of turpentine. I found that Persian naphtha began to boil in glass at the temperature of 320°. As the boiling continues the temperature rises. I raised the temperature of Persian naphtha in a silver cup as high as 352°.

At the temperature of 72·5° the vapour of naphtha is capable of supporting a column of mercury 1·78 inch in height. M. T. de Saussure determined its specific gravity by weighing a mixture of vapour of naphtha and common air. He obtained 2·833 as the specific gravity. I tried the specific gravity of the vapour of Persian naphtha at the temperature of 55° by the same method, and found it 2·263. Saussure's experiment was made at the temperature of 72·5°. Probably, therefore, the specific gravity of this vapour increases at a great rate with the temperature. When the vapour of naphtha is mixed with common air, it is not easily removed again. It may be passed, without alteration, through water. Alcohol would no doubt absorb it, and a considerable proportion of it would be condensed by the freezing temperature.

Naphtha burns with a strong yellow flame, and a considerable smoke.

It is insoluble in water; though it communicates its peculiar smell to that liquid. Alcohol dissolves about $\frac{1}{5}$th of its weight of it. Sulphuric ether, petroleum, fat oils, pitch, volatile oil, combine with naphtha in every proportion. It dissolves wax by the assistance of heat, and allows a portion of it to fall down again as it cools. Caoutchouc swells in naphtha to more than 30 times its bulk, and becomes gelatinous and transparent; but scarcely dissolves. However by

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[*] It had been manufactured in Edinburgh.

[†] It had been manufactured in Glasgow.

[‡] Determined by Saussure, Annals of Philosophy, x. 119.

this means it is easy to mould caoutchouc into tubes of considerable service to the chemist.*

Naphtha dissolves a little sulphur and phosphorus when assisted by heat, and lets them fall again in the state of crystals. Neither the fixed alkalies nor the strong mineral acids have any marked action on naphtha. It is known that anhydrous potash combines with it and forms a brown soap; but the hydrous alkalies do not unite with it. It absorbs about $2\frac{1}{2}$ times its volume of ammoniacal gas.

When naphtha is passed through a red hot porcelain tube, it is converted into charcoal, a brown empyreumatic oil, which, when sublimed at the temperature of 95°, yields a portion of colourless crystals in rhomboidal plates, having a lustre similar to that of spermaceti,† and a quantity of carburetted hydrogen gas. Theodore de Saussure attempted to analyze naphtha by detonating a mixture of the vapour of naphtha and oxygen gas. The result of his experiments was, that 1 volume of vapour of naphtha requires for complete combustion 14 volumes of oxygen gas, and that after the combustion there remain 8·2 volumes of carbonic acid gas. Of consequence 5·8 volumes of the oxygen must have gone to the formation of water, so that the hydrogen in 1 volume of vapour of naphtha, if in a separate state, would amount to 11·6 volumes. This would make naphtha a compound of

8 atoms carbon ...... = 6·0
12 atoms hydrogen .... = 1·5

7·5

He himself however concludes from his analysis that naphtha is a compound of

$$\left.\begin{array}{l}\text{6 volumes vapour of carbon}\\ \text{5 volumes hydrogen gas}\end{array}\right\}\text{condensed into 1 volume,}$$

or which is the same thing of

6 atoms carbon .... 4·5
5 atoms hydrogen ...... 0·625

5·125

with about 1 per cent. of azote.‡

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* See Mr. Syme's paper, Annals of Philosophy, xii. 112.

† This I consider as the same with the substance first noticed by Mr. Garden (Annals of Philosophy, xv. 74). I have analyzed it, and found it a compound of 2 atoms carbon + 1 atom hydrogen.

‡ Annals of Philosophy, x. 118.

Composition.

I subjected naphtha from Persia to analysis by heating it in a copper tube along with peroxide of copper. 1 grain of naphtha by this treatment yielded 6·5 cubic inches of carbonic acid, and 1·35 grain of water. Now the hydrogen in 1·35 gr. of water is equivalent to 7 cubic inches, and the carbon in 6·5 cubic inches of carbonic acid is equivalent to 6·5 cubic inches. Hence naphtha is composed of

6·5 volumes of carbon, or	13 volumes
7 volumes of hydrogen	14 volumes

Substituting atoms for volumes we have naphtha composed of

13 atoms carbon ...... =	9·75
14 atoms hydrogen .... =	1·75
	11·50

	Grains.
6½ cubic inches of carbon weigh ..	0·822
7 cubic inches of hydrogen weigh	0·148
	0·970

So that in this analysis there is a deficiency of three per cent. which I am disposed to ascribe to the presence of azote as a constituent of naphtha in that proportion.*

Sea-wax.

2. *Sea-wax*, or *maltha*, is a solid substance found on the Baikal lake in Siberia. It is white, melts when heated, and on cooling assumes the consistence of white cerate. It dissolves readily in alcohol, and in other respects appears to possess the characters of a solid volatile oil. Its properties, however, have been but imperfectly examined. Klaproth found that a similar substance was obtained by distilling a species of *wood coal*, called *earth coal* by the Germans.†

Mineral tallow.

The substance described by Kirwan under the name of *mineral tallow*, and said to have been found on the coast of Finland, in the Swedish lakes, and in a fountain near Strasburgh, seems to approach very nearly to sea-wax. Its specific gravity is 0·770. It is white, brittle, stains paper like oil, melts when heated, and burns with a blue flame and much smoke; dissolves imperfectly in hot alcohol, but readily in olive oil.‡

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* Annals of Philosophy, xv. 307.

† Beitrage, iii. 325.

‡ Kirwan's Mineralogy, ii. 47.

SECT. II.

PROPER BITUMENS.

THE true bituminous substances may be distinguished by the following properties:

Characters.

1. They are either solid or of the consistence of tar.

2. Their colour is usually brown or black.

3. They have a peculiar smell, or at least acquire it when rubbed. This smell is known by the name of the *bituminous* odour.

4. They become electric by friction, though not insulated.*

5. They melt when heated, and burn with a strong smell, a bright flame, and much smoke.

6. They are insoluble in water and alcohol, but dissolve most commonly in ether, and in the fixed and volatile oils.

7. They do not dissolve in alkaline leys, nor form soap.

8. Acids have little action on them; the sulphuric scarcely any: the nitric, by long and repeated digestion, dissolves them, and converts them into a yellow substance, soluble both in water and alcohol, and similar to the product formed by the action of nitric acid on resins.†

The bitumens at present known may be reduced to three; namely, *asphaltum*, *mineral tar*, and *mineral caoutchouc*. Bitumen has been found also united to a resinous compound, in a curious substance first accurately examined by Mr. Hatchett, to which he has given the name of *retinasphaltum*. United to charcoal in various proportions, it constitutes the numerous varieties of *pit-coal*, so much employed in this country as fuel.

Asphaltum.

1. Asphaltum. This substance occurs in great abundance in different countries, especially in the island of Trinidad, on the shores of the Dead Sea, and in Albania, where it is found in vast strata. It is supposed that it was first liquid, and that it acquired solidity by exposure to the air.

Its colour is black, with a shade of brown, red, or grey. Its specific gravity varies. That of Albania, as ascertained by Klaproth, was 1·205;‡ but it was somewhat contaminated with earth. Kirwan, in purer specimens, found the specific gravity to vary from 1·07 to 1·165.§ Klaproth has published an analysis of the asphaltum of Albania.

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* Haüy. † Hatchett. ‡ Beitrage, iii. 315.

§ Mineralogy, ii. 46.

Properties.

He found it insoluble both in acids and alkalies, as also in water and alcohol; but soluble in oils, petroleum, and sulphuric ether. Five parts of rectified petroleum dissolved 1 part of asphaltum without the assistance of heat, and formed a blackish brown solution, which by gentle evaporation left the asphaltum in the state of a black brown shining varnish. The solution in ether was of a pale brown red colour; and when evaporated, the asphaltum remained in the state of a semi-fluid substance of a reddish colour, still insoluble in alcohol.

Action of heat.

A hundred grains of this asphaltum being distilled in a retort, by a heat gradually raised to redness, yielded the following products:

	Grains.
36 cubic inches (German) of heavy inflammable air	16
A light brown fluid oil	32
Water slightly tainted with ammonia	6
Charcoal	30
Ashes	16
	100

These ashes consisted chiefly of silica and alumina, with some iron, lime, and manganese.*

Uses.

The asphaltum found in Albania is supposed to have constituted the chief ingredient of the *Greek fire*. The Egyptians are said to have employed this bitumen in embalming. It was called *mumia mineralis*.† The ancients inform us that it was used instead of mortar in building the walls of Babylon.

Mineral tar.

2. Asphaltum is seldom absolutely pure; for when alcohol is digested on it, the colour of the liquid becomes yellow, and by gentle evaporation a portion of petroleum is separated.‡ *Mineral tar* seems to be nothing else than asphaltum containing a still greater proportion of petroleum. When alcohol is digested on it, a considerable quantity of that oil is taken up; but there remains a black fluid substance like melted pitch, not acted upon by alcohol, and which therefore appears to possess the properties of asphaltum, with the exception of

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* Klaproth's Beitrage, iii. 316.

† Watson's Chem. Essays, iii. 4.

‡ Hatchett's Observations on the Change of some of the Principles of Vegetables into Bitumen. Phil. Trans. 1804.

not being solid.* By exposure to the air, it is said to assume gradually the state of asphaltum.

Mineral caoutchouc.

3. Mineral caoutchouc is a singular substance, hitherto found only in Derbyshire. It is soft and very elastic, not unlike *common caoutchouc*, or *Indian rubber*, and, like that substance, it may be employed to efface pencil marks from paper; but it soils the paper a little. Its colour is dark-brown, sometimes with a shade of green, at other times of red. The first account of it was published by Dr. Lister in the Philosophical Transactions for 1673.† It occurred in an old forsaken mine in Derbyshire. He calls it a subterraneous fungus, and is uncertain whether it belongs to the vegetable or mineral kingdoms; but rather inclines to the former opinion, and hints that it may have grown out of the old birch props used in the mine. It was first accurately described by Mr. Hatchett. Delametherie first examined its properties; and an analysis of it has been published by Mr. Klaproth.

Properties.

According to Klaproth, it resists the action of almost all liquid menstrua; neither alcohol, alkalies, nor nitric acid affecting it. Even oils were not found by him to dissolve it, though Delametherie assures us that he obtained a solution of it in olive oil.‡ Petroleum succeeded best with Klaproth, assuming a bright yellow colour, while the caoutchouc was rendered transparent. § When heated it melts, takes fire, and burns with a bright flame and a bituminous smell. The melted mass still continues adhesive, and may be drawn out into threads. It is now soluble in oils. ||

Action of heat.

One hundred grains of this substance being distilled in a retort gradually raised to a red heat, yielded the following products:

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* Chemists and mineralogists have united mineral tar to petroleum as a variety. If it be true that *pure* petroleum is insoluble in alcohol, that arrangement is right; but I suspect a mistake. I had no opportunity of trying *naphtha*; but the purest petroleum I have been able to procure readily yields to alcohol, unless it has been left exposed to the air.

† Vol. viii. p. 6179.

‡ Jour. de Phys. xxxi. 312.

§ Beitrage, iii. 109.

|| Klaproth, ibid.

	Grains.
38 cubic inches (German) of heavy inflammable air 4 inches (German) of carbonic acid gas	13·75
A brown thin bituminous oil	73·0
Water slightly acidulous	1·5
Charcoal	6·25
Ashes	5·5
	100·00

The ashes consisted of lime and silica, with some iron, sulphate of lime, and alumina.*

Mr. Hatchett supposes the elasticity of this substance to be owing to a quantity of air confined between its pores.

Retinasphaltum.

4. The *retinasphaltum* of Mr. Hatchett is a substance hitherto found only accompanying *Bovey coal*, in Devonshire.† It was first mentioned by Dr. Milles; but we are indebted to Mr. Hatchett for every thing known respecting its chemical properties.

This substance has a pale brown ochre yellow colour. It is very brittle, and breaks with a vitreous fracture. Its specific gravity is 1·135. When held in the hand for some time, it emits a slightly resinous smell. When heated it melts, smokes, burns with a bright flame, and emits a fragrant odour, at last tainted with a bituminous smell. The melted mass, when cold, is black and brittle, and breaks with a glassy fracture.

Water does not act upon it; but it is partially dissolved by alcohol, potash, and nitric acid; the dissolved portion having the properties of a resin; the undissolved, of asphaltum. Mr. Hatchett analyzed it, and found it composed of‡

55	resin
41	asphaltum
3	earths
99	

Pit-coal of two kinds.

5. Pit-coal, one of the most useful of all the mineral productions, has been divided by mineralogists into various species,

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* Klaproth, Beitrage, iii. p. 110.

† Unless the substance found near Halle, and analyzed by Bucholz, be similar. See Schweigger's Journal, i. 290.

‡ Hatchett, on the Change of some of the Principles of Vegetables to Bitumen. Phil. Trans. 1804.

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according to its external appearances, and the nature of the strata in which it is found; but in a chemical point of view, its most important varieties may be distinguished into two sets: 1. Those that still contain several *vegetable principles*, strictly so called, and thus give evident marks of their origin. To this head belong most of the varieties of coal arranged by Werner, under the head of *brown coal.* Mr. Hatchett has shown, that in some of the substances belonging to this class there is to be found a portion of *vegetable extract;* in others, as in Bovey coal, a portion of *resin;* besides the charcoal and bitumen, which constitute the greatest part of its constituents. From another species of brown coal Klaproth obtained, by means of alcohol, a brown red tincture, which left behind it, on evaporation, a reddish bitter *extract*, partially soluble in water.* 2. Those kinds of coal that contain no traces of unaltered *vegetable principles*, but are composed of various proportions of bitumen and charcoal, contaminated like the former with earthy matter. To this head belong the varieties of coal arranged by Werner under the name of *black coal*, which abound so much in Britain.

1. Brown coal,

2. Black coal,

British species.

The different species of black coal which occur in Great Britain and Ireland, so far as I have had an opportunity of examining them, are five. They have been distinguished by the following names:

1 Kilkenny coal.
2 Caking coal.
3 Splint coal.
4 Cherry coal.
5 Cannel coal.

Kilkenny,

1. Kilkenny coal, so called because found at Kilkenny in Ireland, belongs to the Glance coal of Werner. It has a semimetallic lustre; does not soil the fingers. Its specific gravity is 1·4354. It consumes without flame, and, when completely burnt, leaves 4 per cent. of light-brown ashes, consisting chiefly of silica and iron.

Caking,

2. Caking coal, is so called because when heated it fuses into a kind of bituminous matter, in consequence of which all the pieces of coal, however small, cohere together into a cake. It occurs abundantly in the neighbourhood of Newcastle and Sunderland, in Fife, at Bannock-burn, and in the Glasgow coal formation.

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* Beitrage, iii. 322.

Its colour is velvet black.—Lustre shining, resinous.—Principal fracture straight slaty; cross fracture partly small grained uneven, when the lustre is only glistening; partly small conchoidal when the lustre is shining.—Soft, and very easily frangible.—Fragments cubical—brittle—soils the fingers.—Specific gravity 1·269. It catches fire very easily, and burns with a lively yellow flame; but in consequence of its caking property, it must be frequently stirred to admit the access of air, otherwise it is extinguished.

Splint, 3. The splint coal occurs abundantly in the neighbourhood of Glasgow, constituting the fifth of the six Glasgow beds. It is a well characterized species, and constitutes the most valuable of the Glasgow coals, selling at a higher price than any of the other species. It is the only coal in the neighbourhood of Glasgow used for the manufacture of coke.

Colour black, with a shade of brown—lustre between glimmering and glistening; resinous—principal fracture imperfect curve slaty. Cross fracture fine grained uneven and splintery—not harder than caking or cherry coal, but much more difficulty frangible—fragments wedge-shaped—specific gravity 1·290. It requires a much higher temperature to kindle it than either caking or cherry cool. It burns with flame, and is much more durable than cherry coal.

Cherry, 4. Cherry coal abounds in the neighbourhood of Glasgow and in Staffordshire, near Birmingham.

Colour velvet black, with a slight shade of grey; lustre in some places splendent, in others, shining. Where the lustre is shining, the coal has exactly the appearance of caking coal; but it is easily distinguished from that species by not melting or softening when heated—kind of lustre resinous.—Principal fracture straight slaty: the different layers differ in their lustre, some being splendent, others shining. When the lustre is splendent, the surface is specular; but when only shining, it is merely even—cross-fracture flat conchoidal, and specular splendent—equally hard with caking coal, and very easily frangible—fragments rectangular—very brittle—specific gravity 1·265. When exposed to heat, it readily catches fire, and burns with a clear yellow flame, and giving out a great deal of heat.

Cannel, 5. Cannel coal is so called, because it burns like a candle when lighted, and is often employed as a substitute for candles. It abounds at Wigan, is found near Coventry, in Airshire, and in Lanarkshire.

Colour dark greyish black; sometimes brownish black—lustre glistening, resinous—admits of a good polish, and is often cut into ornaments like jet. Fracture large and flat conchoidal. In the great it is frequently slaty—fragments sometimes cubic, sometimes wedge-shaped, sometimes amorphous.—About as hard as caking coal—brittle—does not soil the fingers—much more difficultly frangible than caking coal or cherry coal; but more easily than splint coal.—Specific gravity 1·272.

The following table exhibits the quantity of earthy matter usually found in 100 parts of each of these coals.

1. Kilkenny coal	4 per cent.
2. Caking coal	1·5
3. Splint coal	9·5
4. Cherry coal	10
5. Cannel coal	11

Composition.

The following table exhibits the quantity of coke which 1000 parts of each of these species of coal forms.

	Weight of coal employed.	Weight of coke formed.	Volatile matter dissipated.	Weight of coal, excluding ashes.	Weight of coke, excluding ashes.	Volatile matter.
Kilkenny coal	1000	867·0	133·0	1000	861·4	138·6
Caking coal	1000	774·0	226·0	1000	770·6	229·4
Splint coal	1000	647·3	352·7	1000	610·3	389·7
Cherry coal	1000	522·5	477·5	1000	469·4	530·6
Cannel coal	1000	400·0	600·0	1000	325·8	674·2

I determined the constituents of these different species by heating them in contact with peroxide of copper. The following tables exhibit the results of these experiments.*

I. CONSTITUENTS BY WEIGHT.

	Carbon.	Hydrogen.	Azote.	Oxygen.	Total.
Kilkenny coal	92·92	0·00	0·00	7·08	100
Caking coal	75·28	4·18	15·96	4·58	100
Splint coal	75·00	6·25	6·25	12·50	100
Cherry coal	74·45	12·40	10·22	2·93	100
Cannel coal	64·72	21·56	13·72	0·00	100

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* Annals of Philosophy, xiv. 81.

II. CONSTITUENTS IN ATOMS.

Chap. I.

	Carbon.	Hydrogen.	Azote.	Oxygen.	Total number of atoms.
Kilkenny coal	35	0	0	2	37
Caking coal	33	11	3	1·5	48·5
Splint coal	28	14	1	3½	46·5
Cherry coal	34	34	2	1	71
Cannel coal	11	22	1	0	34

DIVISION II.

OF SECONDARY COMPOUNDS.

By the term *secondary compound* is meant a body composed of two or more primary compounds united together. The secondary compounds, as far as we are hitherto acquainted with them, consist chiefly of the salifiable bases united with certain oxides of compound combustibles, and with all the acids. I thought it better to give an account of the combinations of the salifiable bases with the acids of chlorine, iodine, fluorine, and cyanogen, while treating of these acids themselves in the last *division*. All the secondary compounds, therefore, which remain to be described in this place may be arranged under the four following heads:

1. Hydrates.	3. Hydrosulphurets.
2. Salts.	4. Soaps.

Each of the classes of bodies will occupy our attention in the four following chapters.

CHAP. I.

OF HYDRATES.

By *hydrate* is meant a chemical combination of a body with water. The term was first employed by Proust, and applied by him to certain combinations of a metallic oxide and water, which he showed to possess properties very different from those of the oxides in a pure state. Davy, D'Arcet, Berard, and especially Dalton, afterwards determined the composition of a variety of hydrates. The composition of many saline hydrates was afterwards determined with much precision by Berzelius, who endeavoured to generalize the subject. According to him, in all saline hydrates the quantity of oxygen in the water is always a multiple of the quantity of oxygen in the base of the salt. Thus *green vitriol* or *protosulphate of iron* in crystals, is composed of

Berzelius' law.

Sulphuric acid	28·97		
Protoxide of iron ..	26·08	containing of oxygen	5·84
Water	46·00	containing of oxygen	40·89

Now 5·84 × 7 = 40·88, which is just the quantity of oxygen in the water. This law pointed out by Berzelius holds pretty generally, though it is not of the importance which he has attached to it. It must always hold when the salifiable base is a protoxide. Thus, in the present case, protosulphate of iron is a compound of

1	Atom sulphuric acid
1	Atom protoxide of iron
7	Atoms of water.

The protoxide of iron contains 1 atom oxygen, and the water contains 7 atoms. Now it is obvious that 7 is a multiple of 1. And whatever number of atoms of water had existed in the salt, still the oxygen in them would have been a multiple of the oxygen in the protoxide of iron. If the salifiable base be a deutoxide, or tritoxide, the rule may hold in certain cases, but certainly not in all.

As I have already, while treating of the different substances which have the property of combining with water, given an account of the different hydrates, as far as we are acquainted with them, I do not consider it as necessary to repeat the description of them here. But I shall insert the following table, exhibiting the composition of the respective hydrates as far as the subject has been investigated.

Table of hydrates.

	Atoms base.	Atoms water.	Weight of base.	Weight of water.
Hydrate of potash	1	1	100	18·75
Hydrate of soda	1	1	100	28·10
Hydrate of lime	1	1	100	31·03
Protohydrate of barytes	1	1	100	11·53
Pentehydrate of barytes	1	5	100	57·69
Eikostahydrate of barytes	1	20	100	230·76
Hydrate of strontian	1	1	100	17·3
Dodecahydrate of strontian	1	12	100	207·69
Hydrate of magnesia	1	1	100	45
Deutohydrate of alumina	1	2	100	105·88
Perhydrate of copper	1	1	100	11·25
Hydrate of tin	1	2	100	24
Hydrate of boracic acid	1	2	100	78·26
Hydrate of phosphorous acid	1	1	100	32
Protohydrate of sulphuric acid	1	1	100	22·5
Deutohydrate of sulphuric acid	1	2	100	45
Tritohydrate of sulphuric acid	1	3	100	67·5
Decahydrate of sulphuric acid	1	0	100	225
Protohydrate of nitric acid	1	11	100	13·23
Deutohydrate of nitric acid	1	2	100	26·46
Tritohydrate of nitric acid	1	3	100	39·69
Tetrahydrate of nitric acid	1	4	100	52·92
Pentahydrate of nitric acid	1	5	100	66·15
Protohydrate of acetic acid	1	1	100	14·5
Deutohydrate of acetic acid	1	2	100	29·0
Tritohydrate of acetic acid	1	3	100	43·5
Crystallized oxalic acid	1	4	100	99·84
Crystallized tartaric acid	1	1	100	13·43
Crystallized citric acid	1	2	100	30·5
Octahydrate of muriatic acid	1	8	100	194·59

CHAP. II.

OF SALTS.

Definition.

The word salt was originally confined to *common salt;* a substance which has been known and in common use from the remotest ages. It was afterwards generalized by chemists, and employed by them in a very extensive and not very definite sense. Every body which is sapid, easily melted, soluble in water, and not combustible, has been called a *salt.*

Salts were considered by the older chemists as a class of bodies intermediate between earths and water. Many disputes arose about what bodies ought to be comprehended under this class, and what ought to be excluded from it. Acids and alkalies were allowed by all to be salts; but the difficulty was to determine concerning earths and metals; for several of the earths possess all the properties which have been ascribed to salts, and the metals are capable of entering into combinations which possess saline properties.

In process of time, however, the term *salt* was restricted to three classes of bodies; namely, *acids*, *alkalies*, and the *compounds* which acids form with alkalies, earths, and metallic oxides. The first two of these classes were called *simple salts;* the salts belonging to the third class were called *compound* or *neutral*. This last appellation originated from an opinion long entertained by chemists, that acids and alkalies, of which they are composed, were of a contrary nature, and that they counteracted one another; so that the resulting compounds possessed neither the properties of acids nor of alkalies, but properties intermediate between the two.

Chemists have lately restricted the term *salt* still more, by tacitly excluding acids and alkalies from the class of salts altogether. At present, then, it denotes only the compounds formed by the combination of acids with alkalies, earths, and metallic oxides.*

No part of chemistry has been cultivated with more zeal than the salts, especially for these last 40 years. During that time the number of saline bodies has been enormously increased, and the properties of a very great number have been determined with precision. Still, however, this wide and important region is far from being completely explored.

Number of salts.

Chemists have agreed to denominate the salts from the acids which they contain: the earth, alkali, and metallic oxide, combined with that acid, is called the *base* of the salt. Thus common salt being a compound of muriatic acid and soda, is called a *muriate*, and soda is called the base of common salt. Now since there are 52 acids and at least 30 bases, it would appear, at first sight, that there are 1560 salts. But there are several acids capable of combining with two bases at once. Thus the tartaric acid combines at once with potash and soda. Such

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* The terms *salt* and *neutral salt* are often confounded. In this Work the epithet *neutral* is confined to salts having no excess of acid or base.

Triple salts.

combinations are called *triple salts*, and they increase the number of salts considerably. There are some salts, too, which are capable of combining with an additional dose of their acid, and others which combine with an additional dose of their base. The French chemists denote the first of these combinations by adding to the usual name of the salt the phrase *with excess of acid*, or by prefixing to it the word *acidulous:* they denote the second by subjoining the phrase with *excess of base.* This method has the merit of being precise; but it is awkward and tedious. The ingenious mode of naming these combinations proposed by Dr. Pearson is preferable. It is equally precise, and far more convenient in every respect. It consists in prefixing to the usual name of the salt the preposition *super*, to denote an excess of acid, and the preposition *sub* to denote an excess of base.* Thus *sulphate of potash* denotes the salt in its state of perfect neutralization, without any excess either of the sulphuric acid or of the potash; *supersulphate of potash* is the same salt with an excess of acid; *subsulphate of potash* is the same salt with excess of base.† These three different kinds of salts must increase the number of saline compounds very considerably: but the precise number of salts is not known, as many of them remain still un-examined by chemists. Probably there are not much fewer than 2000. Some idea may be formed of the progress which this branch of chemistry has made, by recollecting that 40 years ago not more than 30 salts in all were known.

Supersalts and subsalts.

Of these 2000, however, a considerable number may be considered as still unknown, as they have been merely formed without being examined. Of those which are known, the greater number have not been applied to any use, and therefore do not deserve a very particular description.

Nomenclature.

As the different genera of salts are denominated from their acids, it is evident that there must be as many genera as there are acids. The terminations of the names of these genera differ according to the nature of the acid which constitutes them. When that acid contains a maximum of oxygen, the termination of the genus is *ate;* when it does not contain a maximum of oxygen, the termination of the genus is *ite.*

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* Pearson's Translation of the Chemical Nomenclature, p. 52.

† In most cases the acid in the supersalt is just double of that in the neutral salt. It is therefore better to denote it by prefixing the syllable *bi*. Thus *sulphate of potash* is the neutral salt, *bisulphate of potash* is what is usually denominated supersulphate, or acidulous sulphate.

Thus the salts which contain sulphuric acid are called *sulphates;* those which contain sulphurous acid are called *sulphites.* This distinction is of some consequence, because the salts differ very much, according as the acid is saturated with oxygen or not. The *ites* are seldom permanent; when exposed to the air, they usually attract oxygen, and are converted into *ates.*

Every particular species of salt is distinguished by subjoining to the generic term the name of its base. Thus the salt composed of sulphuric acid and soda is called *sulphate of soda.* Triple salts are distinguished by subjoining the names of both the bases connected by hyphens. Thus the compound of tartaric acid, potash, and soda, is called *tartrate of potash-and-soda.* Another mode of naming these triple salts is sometimes followed. One of the names of the bases is prefixed to the generic name so as to act the part of an adjective. For example, *soda-muriate of rhodium,* means the triple salt composed of muriatic acid, soda, and oxide of rhodium. Sometimes the name of the base prefixed is altered a little, as *ammonio-sulphate of magnesia* (*sulphate of magnesia-and-ammonia ;*) *ferruginous sulphate of zinc* (*sulphate of zinc-and-iron.*) This is a less unwieldy mode of naming the triple salts, but it is not always possible to employ it in our language.

Arrangement.

Before the correction of the chemical nomenclature by Morveau in 1781, chemists usually referred the genera of salts to the bases, and distinguished the species by the acids. That celebrated philosopher entirely reversed the method by introducing the new generic terms formed from the acids; and his ingenious nomenclature having been sanctioned and improved in 1787 by Lavoisier, Berthollet, and Fourcroy, who joined with him in forming a new chemical nomenclature, has now become universally prevalent. But after considering the subject with considerable attention, I think the mode of arranging the salts according to the bases is attended with such advantages as to induce me to adopt it in this work. I shall therefore divide this chapter into 32 sections, allowing a section for the salts formed by the combination of each salifiable base with the different acids.

SECT. I.

SALTS OF AMMONIA.

Chap. II. Properties.

1. The salts of ammonia, with a very few exceptions are all soluble in water.

2. When potash or quicklime is mixed with an ammoniacal salt a smell of ammonia is emitted.

3. If to an ammoniacal salt dissolved in water a little salt containing magnesia be added, and afterwards some phosphate of soda dropped in, a copious white precipitate falls.

4. When an ammoniacal salt is exposed to heat, it is completely dissipated in vapours; except when the acid has a fixed metal or phosphorus for its base, in which last case the acid alone remains behind.

5. The ammoniacal salts are not precipitated by infusion of nut-galls or ferrochyazate of potash.

6. When a solution of platinum is dropped into a salt of ammonia, an orange-coloured precipitate falls.

This genus of salts has been very fully investigated. The following are the different species.

Nitrate of ammonia.

Sp. 1. *Nitrate of ammonia.* This salt has been long known: it was formerly distinguished by the names of *nitrum semivolatile* and *nitrum flammans.* Berthollet examined it in the course of his experiments on the component parts of nitric acid: and Sir H. Davy has added considerably to our knowledge of its composition and decomposition.* It may be prepared by dissolving carbonate of ammonia in diluted nitric acid, and evaporating the solution till the salt crystallizes.

Properties.

The appearance of this salt varies very much, according to the temperature at which its solution is evaporated. In a moderate heat, 70° or 100° for instance, and by slow cooling, it is obtained in six-sided prisms, terminated by long six-sided pyramids. When the solution is evaporated at the temperature of 212°, the crystals are channelled and have a fibrous texture, or they are formed of long soft elastic threads. When dried in a heat of about 300°, it assumes the form of a white compact mass. These differences are owing to different proportions of water of crystallization which the salt contains.

Nitrate of ammonia has a very acrid, bitter, disagreeable taste. Its specific gravity is 1·5785.† At the temperature of 60° this salt is soluble in two parts of water: it dissolves in

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* Davy's Researches, p. 71.

† Hassenfratz, Ann. de Chim. xxviii. 12

half its weight of boiling water.[*] It must be observed, however, that its solubility varies with the proportion of water of crystallization which it contains. When exposed to the air, nitrate of ammonia soon attracts moisture and deliquesces.

When this salt, in the state of fibrous or prismatic crystals, is heated, it becomes fluid at a temperature below 300°; between 360° and 400° it boils without decomposition; but when heated to 450°, or somewhat higher, it is gradually decomposed, without losing its water of crystallization. Compact nitrate, on the other hand, undergoes little or no change till it is exposed to a temperature higher than 260°. Between 275° and 300° it sublimes slowly without decomposition, and without becoming fluid. At 320° it melts, and at the same time is partly decomposed, partly sublimed.[†]

When this salt is decomposed in a temperature not exceeding 500°, it is wholly converted into protoxide of azote and water. From the experiments of Davy, it appears that these products are nearly in the proportion of four parts of gas to three parts of water.[‡] It is easy to see that (abstracting the water of crystallization) it must be decomposed into

Water	3·375	or	30
Protoxide of azote	5·5		44

Now this is nearly in the proportion of 3 parts of water to $4\frac{1}{2}$ parts of protoxide of azote. When it is exposed to a heat above 600°, this salt explodes, and is totally decomposed, being converted into nitrous acid, nitrous gas, water, and azotic gas. This phenomenon, observed long ago, induced the older chemists to give the salt the name of *nitrum flammans*. The nature of the decomposition was first ascertained by Berthollet, and more lately it has been examined by Davy.

Composition.

The following table exhibits the constituents of this salt according to the experiments hitherto made upon it by chemists:

	§	‖	**	††	††	††	‡‡
Acid ..	57 ..	64·5 ..	65 ..	69·5 ..	72·5 ..	74·5 ..	76·06
Base ..	23 ..	32·1 ..	$23\frac{1}{3}$ ..	18·4 ..	19·3 ..	19·8 ..	23·94
Water.	20 ..	3·4 ..	$11\frac{2}{3}$ ..	12·1 ..	8·2 ..	5·7	
Total ..	100 ..	100·0 ..	100·0 ..	100·0 ..	100·0 ..	100·0	100·00

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[*] Fourcroy, iii. 195, Eng. Trans.

[†] Davy, p. 85.

[‡] Ibid. p. 105.

[§] Kirwan, Nicholson's Jour. iii. 215.

[‖] Wenzel, p. 83.

[**] Ure, Annals of Philosophy, x. 204 and 205.

[††] Davy's Researches, p. 71. In the first of these analyses the salt was prismatic, in the second fibrous, and in the third compact.

[‡‡] Theoretic composition.

Sp. 2. *Nitrite of ammonia.* This salth as not hitherto been examined.

3. Carbonate.

Sp. 3. *Carbonate of ammonia.* This salt has been long known. It is often obtained by distilling animal substances: but for chemical purposes it is best to extract it from sal ammoniac by means of chalk. Two parts of chalk and 1 part of sal ammoniac, both as dry as possible, are mixed together and put into an earthen retort. On the application of a sufficient heat, carbonate of ammonia sublimes, and is obtained in the state of a white crystallized mass. There are two subspecies of it, the carbonate and bicarbonate.

Subspecies 1. *Carbonate.* This salt may be obtained in crystals, but they are so small and so irregular, that it is difficult to ascertain their form. According to Bergman, they may be obtained in octahedrons, having, for the most part, their two opposite apexes truncated.* The taste and smell of this salt, though much weaker, are the same with those of pure ammonia. Like all the alkaline carbonates, it converts vegetable blues to green, precisely as pure alkalies do. Its specific gravity is 0·966.† It is soluble in rather less than twice its weight of cold water. Hot water dissolves its own weight of it. Boiling water cannot be employed, because at that heat the carbonate is volatilized. When heated it evaporates very speedily.

When in its perfect state this subspecies is composed of 1 atom carbonic acid and 1 atom ammonia, or by weight of

Carbonic acid ..	2·75	56·41	100
Ammonia	2·125	43·59	77·27
		100·00	

But the longer it is kept, the greater is the proportion of carbonic acid and the smaller the proportion of ammonia which it contains. Because the alkali gradually makes its escape into the atmosphere. I have obtained it from shops in London composed as follows:

Carbonic acid ..	55·70	100
Ammonia	26·17	46·98
Water	18·13	
	100·00	

So that it had lost within one-fifth part of half of its ammonia.

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* Bergman, i. 21.

† Hassenfratz, Ann. de Chim. xxviii. 12.

Properties.

Subspecies 2. *Bicarbonate.* This salt may be obtained by exposing the common carbonate of ammonia in powder to the air, or by causing a current of carbonic acid gas to pass through a solution of it in water. It crystallizes in six-sided prisms, usually small, has no smell, and less taste than the subcarbonate. According to the experiments of Schrader, it is composed of about

56	acid
19	base
25	water
100*	

Its true composition is

Acid	100
Base	38·63

4. Borate.

Sp. 4. *Borate of ammonia.* This salt has been described by Wenzel. It forms permanent crystals, which have a considerable resemblance to borax. When heated the ammonia flies off, carrying with it a portion of the acid, but leaving a part of it in a state of purity. From the experiments of Wenzel, its constituents are,†

100	acid
34	base and water

Its true composition is obviously,

Acid	2·875	100
Base	2·125	73·91

Berzelius analyzed this salt, and obtained the following result:

Acid	37·95	100
Ammonia	30·32	79·895
Water	31·73	
	100·00‡	

Sp. 5. *Silicate of ammonia.* This salt is unknown.

6. Phosphate.

Sp. 6. *Phosphate of ammonia.* This salt exists in urine, and seems to have been first accurately distinguished by Rouelle. It was afterwards examined by Lavoisier in 1774, and still more lately by Vauquelin.§ It is usually prepared by satu-

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[*] Gehlen's Jour. ii. 582.

[†] Verwandtschaft, p. 249.

[‡] Annals of Philosophy, iii. 57.

[§] Jour. de l'Ecole Polytechnique.

rating with ammonia the superphosphate of lime obtained from bones, and evaporating the solution to such a consistency, that when allowed to cool the phosphate of ammonia is obtained in crystals.

Properties.

It crystallizes in octahedrons composed of two low four-sided pyramids with square bases. Its taste is saline with some bitterness. Its specific gravity 1·8051.* It is soluble in twice its weight of water at the temperature of 55°, and in rather a smaller proportion of boiling water. It is by spontaneous evaporation that it is obtained in the state of regular crystals. It is not altered by exposure to the air. When heated, it undergoes the watery fusion: it then dries; but if the heat be continued, it swells up, loses its alkaline base, and the acid melts into a transparent glass.

7. Phosphite.

Sp. 7. *Phosphite of ammonia.* This salt is very soluble in water, and crystallizes with difficulty. No experiments have been made to determine its composition, but it is doubtless composed of an atom of acid united to an atom of ammonia.

8. Hypophosphite.

Sp. 8. *Hypophosphite of ammonia.* This salt is very soluble in water and equally soluble in alcohol. It has not been analyzed.

9. Sulphate.

Sp 9. *Sulphate of ammonia.* This salt was discovered by Glauber, and called by him *secret sal ammoniac.* It was also called *vitriolated ammoniac.* It may be prepared by saturating ammonia with sulphuric acid, or by decomposing sal ammoniac by means of sulphuric acid.

Properties.

Its crystals are generally small six-sided prisms, whose planes are unequal, terminated by six-sided pyramids. It has a sharp bitter taste. It is soluble in twice its own weight of water at the temperature of 60°, and in its own weight of boiling water. Water of the temperature of 144° dissolves 0·78 of its weight of this salt.† When exposed to the air, it slowly attracts moisture.

When heated, it first decrepitates, then melts, and in close vessels sublimes, but with some loss of its alkali.‡ In that state it might be called *supersulphate* of ammonia, as it contains an excess of acid, has an acid taste, and reddens vegetable blues. When heated nearly to redness, the greatest part of it is decomposed, some sulphurous acid comes over and some ammo-

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Wenzel, p. 309.

‡ Kirwan's Min. ii. 11.

nia, a great quantity of azotic gas is disengaged, and in all probability water is formed.*

Its constituents have been determined as follows:

Composition.

	†	‡	§	‖	**	**
Acid	54·66	58·75	59·8	60	70·17	100
Base	14·24	41·25	40·2	40	29·83	42·5
Water	31·10					
	100·00	100·00	100·0	100	100·00	

The crystals of sulphate of ammonia contain 3 atoms of water combined with 1 atom of the salt. It does not seem possible to separate the water completely without decomposing the salt.

10. Sulphite.

Sp. 10. *Sulphite of ammonia.* This salt was first described by Fourcroy and Vauquelin.†† It crystallizes in six-sided prisms terminated by six-sided pyramids; or in four-sided rhomboidal prisms, terminated by three-sided summits. Its taste is cool and penetrating, like that of the other ammoniacal salts, but it leaves a sulphureous impression in the mouth. It is soluble in its own weight of cold water, and much cold is produced. Its solubility is increased by heat; so that a saturated boiling solution crystallizes on cooling. When exposed to the air it attracts moisture, and is soon converted into a sulphate. No other sulphite undergoes this change so rapidly. When heated it decrepitates, a little ammonia is disengaged, and the salt then sublimes in the state of supersulphite of ammonia.

There can be no doubt that this salt is composed of

Sulphurous acid	4·000	100
Ammonia	2·125	53·2

If any confidence can be put in the analysis of this salt by Fourcroy and Vauquelin, the crystals seem to consist of 2 atoms of salt united to 1 atom of water.

Sp. 11. *Hyposulphite of ammonia.* According to Mr. Hers-

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* Hatchett, Phil. Trans. lxxxvi. 314.

† Kirwan, Nicholson's Quarto Jour. iii. 215.

‡ Wenzel's Verwandtschaft, p. 58.

§ Richter, Statique Chimique, i. 136.

‖ Ure, Annals of Philosophy, x. 203.

** Theoretic composition.

†† Nicholson's Jour. i. 317.

chell, the only person who has hitherto examined this salt, it is always a compound of 2 atoms acid with 1 atom baze. So that it is a bin-hyposulphite. It does not readily crystallize; but when much concentrated, cools into a confused pappy mass of very minute spiculæ. Its taste is bitingly pungent, succeeded by a disgusting bitterness. When heated, it burns, with a weak flame, and evaporates entirely.*

Sp. 12. *Hyposulphate of ammonia.* Still unexamined.

13. Seleniate.

Sp. 13. *Seleniate of ammonia.* According to Berzelius, ammonia combines with three different proportions of selenic acid, forming *seleniate*, *biseleniate*, and *quadriseleniate* of ammonia.

(1.) *Seleniate* is obtained by adding selenic acid to concentrated caustic ammonia till there be a small excess of acid. When the solution is left in a cool place, the salt precipitates partly in four-sided prisms, and partly in feather-shaped crystals. They deliquesce when exposed to the air.

(2.) The *biseleniate* is formed when the neutral seleniate is dissolved in water, and the liquid is left to spontaneous evaporation. A portion of the ammonia flies off, and the biseleniate is deposited in acicular crystals, which undergo no change, though exposed to the air.

(3.) *Quadriseleniate* is obtained either by heating a solution of biseleniate, or by adding selenic acid to the biseleniate. It does not crystallize, and when evaporated to dryness, speedily absorbs moisture from the atmosphere.†

14. Arseniate.

Sp. 14. *Arseniate of ammonia.* When arsenic acid is saturated with ammonia, the liquid by a careful evaporation (supplying the ammonia in proportion as it escapes) yields four-sided rectangular prisms, terminated at one extremity by a four-sided pyramid, at the other by a bihedral summit. With an excess of acid, it yields needle-form crystals of bin-arseniate of ammonia, which deliquesce when exposed to the air.

When arseniate of ammonia is gently heated, it loses its transparency and part of its alkali. In a strong heat a portion of the ammonia is decomposed, water is formed, arsenic sublimed, and azotic gas disengaged. This was one of the experiments which first led Scheele to the discovery of the component parts of ammonia.‡ This salt has not been analyzed. It is probably a compound of

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* Edinburgh Phil. Jour. i. 19.

† Berzelius, Ann. de Chim. et de Phys. ix. 260

‡ Scheele, i. 145.

Arsenic acid	14·5	100
Ammonia	2·125	14·655

15. Arsenite. Sp. 15. *Arsenite of ammonia.* This salt may be prepared by dissolving arsenious acid in liquid ammonia. A viscid yellow-coloured liquor is obtained which does not crystallize. It has not been examined by modern chemists.

16. Antimoniate. Sp. 16. *Antimoniate of ammonia.* This combination has hitherto been examined by Berzelius only. It may be formed by digesting the hydrate of antimonic acid in caustic ammonia. A neutral solution is gradually formed. If we attempt to evaporate it a portion of the ammonia is disengaged and a white powder falls, which is a superantimoniate of ammonia. It reddens vegetable blues, and when heated in a retort ammonia and water are driven off, and antimonic acid remains behind. This supersalt is not decomposed by exposure to the air for months, even at the temperature of 122°.*

Sp. 17. *Antimonite of ammonia.* This salt has not been examined.

18. Chromate. Sp. 18. *Chromate of ammonia.* This salt has been slightly examined by Vauquelin† and John.‡ It may be formed by saturating chromic acid by ammonia. The salt gradually forms dendritical crystals of a fine yellow colour. When slightly heated it is decomposed, even when in solution brown flocks of chromic oxide precipitating. It has not been analyzed, but is probably a compound of

Chromic acid	6·5	100
Ammonia	2·125	32·69

19. Molybdate. Sp. 19. *Molybdate of ammonia.* This salt dissolves readily in water. The solution does not crystallize, but forms by evaporation a semi-transparent mass. When heated the ammonia is partly driven off, partly decomposed, and the acid is reduced to the state of an oxide.§ It has not been analyzed, but is probably a compound of

Molybdic acid	9	100
Ammonia	2·125	23·61

Sp. 20. *Molybdite of ammonia.* Has not been examined.

21. Tungstate. Sp. 21. *Tungstate of ammonia.* This salt may be formed by dissolving tungstic acid in carbonate of ammonia. By eva-

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* Nicholson's Journal, xxxv. 40.

† Ann. de Chim. lxx. 70.

‡ Annals of Philosophy, iv. 425.

§ Bucholz, Gehlen's Jour. iv. 616.

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porating the solution, the tungstate of ammonia crystallizes, sometimes in small scales resembling boracic acid, and sometimes in four-sided prismatic needles. Its taste is metallic; it is soluble in water, does not deliquesce in the air, and is decomposed completely by heat. Its composition according to Vauquelin is

78 oxide
22 ammonia and water

100*

Its true composition is doubtless,

Tungstic acid	15	 100
Ammonia	2·125	14·6

Comparing this with Vauquelin's analysis, it appears, that 100 parts of the crystallized salt contain 16 of water. So that the crystals are composed of 1 atom salt + 2 atoms water.

Sp. 22. *Columbate of ammonia.* Not yet examined.

23. Acetate.

Sp. 23. *Acetate of ammonia.* This salt may be prepared by saturating acetic acid with ammonia. If the acid and alkali be weak it is difficult to saturate them with each other. It is requisite therefore that they should be both concentrated.[†] It is too volatile to be easily crystallized: It may, however, by gentle evaporation, be made to deposite needle-shaped crystals. Mr. de Lassone crystallized it by sublimation.[‡] When the sublimation is slow, it forms long, slender, flatted crystals, terminating in sharp points, of a pearl-white colour, and about an inch and eight-tenths in length.[§] It impresses the tongue at first with a sense of coldness, and then of sweetness, which is followed by a taste resembling that of a mixture of sugar and nitre, in which the sweet does not predominate over the mawkish taste of the nitre.[||] It is very deliquescent. It melts at 170°, and sublimes at about 250°.[**] When a watery solution of this salt is distilled, there comes over first a quantity of ammonia, next a quantity of acetic acid, and at last of the salt itself containing an excess of acid. No such decomposition takes place when the crystals are distilled by a moderate heat.[††]

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[*] Vauquelin and Hecht, Jour. de Min. No. 19, p. 20.

[†] Steinacher, Jour. de Phys. lxv. 32.

[‡] Mem. Par. 1775. I have often crystallized it by confining the concentrated solution under the exhausted receiver of an air pump along with sulphuric acid.

[§] Higgins on Acetous Acid, p. 183.

[||] Ibid. p. 192.

[**] Ibid.

[††] Ibid.

Its constituents, as determined by Wenzel and Richter, are as follows:

	*	†
Acid	62·45	68·77
Base	37·55	31·23
	100	100

There can be no doubt that the true composition of this salt is as follows:

Acetic acid	6·375	75	100
Ammonia	2·125	25	33·3

An accurate analysis of it would be very difficult to execute.

24. Benzoate.

Sp. 24. *Benzoate of ammonia.* This salt crystallizes with difficulty. Its crystals are feather-shaped. It deliquesces. It is very soluble in water. Benzoate of ammonia has been recommended by Berzelius, as an excellent reagent for precipitating iron from its solution. It throws down this metal of an orange colour, and occasions no insoluble precipitates with any of the other salifiable bases, except tellurium and mercury, and perhaps copper, all of which are thrown down white.[‡]

25. Succinate.

Sp. 25. *Succinate of ammonia.* This salt forms needle-shaped crystals, but it crystallizes with difficulty. It has a sharp, bitter, and cooling taste; when exposed to heat, it sublimes without decomposition.

Succinate of ammonia is much used for precipitating iron from its solutions, which it does only when in the state of peroxide, and then throws it down of a deep flesh-red colour. It likewise precipitates barytes and mercury from their solution in acids. With several other metallic solutions, as copper and lead, it likewise forms white precipitates, which dissolve when sufficiently diluted with water.

26. Moroxylate.

Sp. 26. *Moroxylate of ammonia.* This salt may be formed by pouring carbonate of ammonia into the solution of the moroxylate of lime. The solution, when evaporated, yields crystals of moroxylate of ammonia in long slender prisms.[§]

27. Camphorate.

Sp. 27. *Camphorate of ammonia.* This salt may be prepared by dissolving carbonate of ammonia in hot water, and adding camphoric acid slowly till the alkali is saturated. It must then be evaporated with a very moderate heat, to prevent the

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[*] Wenzel, p. 149.

[†] Richter, Statique Chimique, i. 136.

[‡] Afhandlingar, iii. 152.

[§] Klaproth, Nicholson's Jour. vii. 130.

disengagement of the ammonia. It is very difficult to obtain this salt in regular crystals. When evaporated to dryness, there is left a solid opaque mass of a sharp and bitterish taste. Water at the temperature of about 60° dissolves nearly $\frac{1}{100}$th part of its weight of this salt; boiling water dissolves $\frac{1}{3}$d of its weight: But all the alkaline camphorates are much more soluble when there is an excess of base. It is completely soluble in alcohol.

When exposed to the air it attracts moisture, but not in sufficient quantity to enable it to assume a liquid form. When exposed to heat it swells, melts, and is converted into vapour. Before the blow-pipe it burns with a blue and red flame, and is entirely volatilized. Most of the calcareous salts form triple salts with camphorate of ammonia. It decomposes in part all the aluminous salts except the sulphate of alumina.*

Sp. 28. *Boletate of ammonia.* This salt has been described in a preceding part of this vol. p. 156.

29. Suberate.

Sp. 29. *Suberate of ammonia.* This salt crystallizes in parallelopipeds. Its taste is saltish, and it leaves an impression of bitterness. It reddens vegetable blues. It is very soluble in water. It attracts moisture from the air. When placed upon burning coals it loses its water of crystallization, and swells up; and before the blow-pipe it evaporates entirely.†

Sp. 30. *Pyrotartrate of ammonia.* Not hitherto examined.

31. Oxalate.

Sp. 31. *Oxalate of ammonia.* When oxalic acid is saturated with ammonia, the solution yields by evaporation oxalate of ammonia crystallized in four-sided prisms, terminated by dihedral summits. The lateral edges are often truncated, so as to make the prism six or eight-sided. Its taste is bitter and unpleasant, somewhat like that of sal ammoniac. The specific gravity of the crystals is 1·582. At the temperature of 60° 100 parts of water dissolve only 4·5 parts of this salt. The specific gravity of the solution is 1·0186. This salt is insoluble in alcohol. When distilled, carbonate of ammonia is disengaged, a little of the acid is sublimed, and a residuum of charcoal remains behind. This salt is much used as a reactive to detect the presence of lime.‡ It is capable of combining with a double dose of acid, and forming a binoxalate. Oxalate of ammonia is a compound of

Oxalic acid	4·5	100
Ammonia	2·125	47·222

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* Ann. de Chim. xxvii. p. 31.

† Ann. de Chim. xxxiii. 55.

‡ Bergman, i. 261.

The analyses both of Berard and myself of this salt were inaccurate, because our oxalic acid was not completely freed from water.

32. Mellate. Sp. 32. *Mellate of ammonia.* When mellitic acid is saturated by ammonia, the solution yields fine transparent six-sided crystals, which become opaque when exposed to the air, and assume the white colour of silver.[*]

33. Tartrate. Sp. 33. *Tartrate of ammonia.* The crystals of this salt are polygonous prisms, not unlike those of tartrate of soda. It has a bitter taste like that of nitre. It is very soluble in water. Heat decomposes it. This salt also, as Retzius affirms, combines with an excess of acid, and forms a supertartrate almost as insoluble in water as tartar.

34. Citrate. Sp. 34. *Citrate of ammonia.* This salt, formed by dissolving carbonate of ammonia in citric acid, does not crystallize till its solution be evaporated to the consistency of a thick syrup. Its crystals are elongated prisms. It is very soluble in water. Its taste is cooling and moderately saline.[†] The ammonia is separated by the application of heat.[‡]

According to Vauquelin, it is composed of

62 acid
38 ammonia
———
100[§]

Its true composition is doubtless

Citric acid	7·375	100
Ammonia	2·125	29·02

Sp. 35. *Saclactate of ammonia.* This salt has an acid taste, always containing an excess of acid. Heat disengages the ammonia.[||]

Sp. 36. *Urate of ammonia.* A white tasteless powder, scarcely distinguishable in appearance from uric acid. It dissolves in an excess of acid.

Sp. 37. *Lactate of ammonia.* Not hitherto examined.

Sp. 38. *Malate of ammonia.* This salt does not crystallize unless there be an excess of acid. In that case it forms permanent crystals insoluble in alcohol.[**]

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[*] Klaproth's Beitrage, iii. 131.

[†] Dobson.

[‡] Scheele.

[§] Fourcroy, vii. 208.

[||] Scheele on sugar of milk.

[**] Donovon, Phil. Trans. 1815.

Sp. 39. *Formate of ammonia.* This salt is soluble in water, and may be sublimed without decomposition.

40. Lactate.

Sp. 40. *Lactate of ammonia.* When concentrated lactic acid is mixed with an excess of caustic ammonia, the mixture acquires a strong volatile smell not unlike that of acetate or formate of ammonia, which however soon ceases. The salt has sometimes a slight tendency to shoot into crystals. It forms a gummy mass, which, when exposed to the air, loses a portion of its base, and acquires an excess of acid. When heated, a great part of the ammonia is disengaged, and a very acid salt remains which deliquesces in the air.* When there is an excess of acid the salt crystallizes in parallelopipeds.†

Sp. 41. *Gallate of ammonia.*

Sp. 42. *Tannate of ammonia.* Neither of these compounds has been examined with care. They do not seem to be of a permanent nature.

Such are the properties of the salts of ammonia. Their composition is easily determined by considering them as composed of 1 atom of ammonia united to 1 atom of each of the acids. The weight of an atom of ammonia is 2·125, and the weights of all the acids, as far as they have been determined, have been given in a preceding chapter of this work.

SECT. II.

SALTS OF POTASH.

General properties.

1. The salts of potash, a very few excepted, are soluble in water. But in general they are less soluble than those of ammonia.

2. Many of them can be obtained in the state of crystals; but many of them likewise refuse to crystallize. In general the salts of potash have a less tendency to form regular crystals than the salts of soda.

3. If tartaric acid, dissolved in water, be dropped into an aqueous solution of a salt of potash, the liquid speedily deposites a white granular sediment. This sediment has a sour taste, and consists of small crystals of cream of tartar.

4. If a solution of sulphate of alumina be dropped into a salt of potash, octahedral crystals of alum are very soon deposited.

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* Berzelius, Djurkemien, ii. 436.

† Braconnot, Ann. de Chim. lxxxvi. 84.

5. The salts of potash may be exposed to a red heat without being volatilized like the salts of ammonia. If the acid contained in the salt be combustible, it is decomposed, and carbonate of potash, mixed with a little charcoal, remains behind. If the acid is not combustible the salt usually fuses and its nature is not altered; though to this there are some exceptions. Thus the nitric acid is gradually decomposed at a red heat, sulphurous acid lets sulphur sublime, and is converted into sulphuric acid, phosphorous acid allows phosphuretted hydrogen to escape, and is converted into phosphoric acid.

6. The salts of potash are not precipitated by infusion of nutgalls nor by ferrochyazate of potash.

7. They are not affected by sulphuretted hydrogen gas, or by the addition of a hydrosulphuret, except when their acid has a metal for its basis. In which case the acid is decomposed and precipitated, and the potash left behind.

8. When a solution of platinum is dropped into a salt of potash, an orange-coloured precipitate appears.

1. Nitrate. Sp. 1. *Nitrate of potash.* As this salt, known also by the name of *saltpetre*, is produced naturally in considerable quantities, particularly in Egypt, it is highly probable that the ancients were acquainted with it: but scarcely any thing certain can be collected from their writings. If Pliny mentions it at all, he confounds it with carbonate of soda, which was known by the names of *nitron* and *nitrum*. It is certain, however, that it has been known in the East from time immemorial. Roger Bacon mentions this salt in the 13th century under the name of *nitre*.

Origin. No phenomenon has excited the attention of chemical philosophers more than the continual reproduction of nitre in certain places after it had been extracted from them. Prodigious quantities of this salt are necessary for the purposes of war; and as nature has not laid up great magazines of it, as she has of some other salts, this annual reproduction is the only source from which it can be procured. It became, therefore, of the utmost consequence, if possible, to discover the means which nature employed in forming it, in order to enable us to imitate her processes by art, or at least to accelerate and facilitate them at pleasure. Numerous attempts accordingly have been made to explain and to imitate these processes.

Stahl, setting out on the principle that there is only one acid in nature, supposed that nitric acid is merely sulphuric acid combined with phlogiston, and that this combination is produced by putrefaction; he affirmed, accordingly, that nitre is composed by uniting together potash, sulphuric acid, and phlogiston. But this opinion, which was merely supported by very far-fetched analogies, could not stand the test of a rigorous examination.

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Lemery, the younger, accordingly advanced another, affirming, that all the nitre obtained exists previously in animals and vegetables, and that it is formed in these substances by the processes of vegetation and animalization. But it was soon discovered that nitre exists, and is actually formed, in many places where no animal nor vegetable substance had been decomposed: and consequently this theory was as untenable as the former. So far indeed is it from being true, that nitre is formed by these processes alone, that the quantity of nitre in plants has been found to depend entirely on the soil in which they grow.*

At last, by the numerous experiments of several French philosophers, particularly by those of Thouvenel, it was discovered that nothing else is necessary for the production of nitre but a basis of lime, heat, and an open, but not too free communication with dry atmospheric air. When these circumstances combine, the acid is first formed, and afterwards the alkali makes its appearance. How the air furnishes materials for this production is easily explained, now that the component parts of the nitric acid are known to be oxygen and azote: but how lime contributes to their union it is not so easy to see. The appearance of the potash is equally extraordinary.

Preparation.

Nitre is found abundantly on the surface of the earth in India, South America, South Africa, and even in some parts of Spain. In Germany and France it is obtained by means of artificial *nitre* beds. These consist of the refuse of animal and vegetable bodies undergoing putrefaction, mixed with calcareous and other earths. It has been ascertained, that if oxygen gas be presented to azote at the instant of its disengagement, nitric acid is formed. This seems to explain the origin of the acid in these beds. The azote disengaged from these putrefying animal substances combines with the oxygen of the air. The potash is probably furnished, partly, at least, by the vegetables and the soil.

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* Bouillon.

The nitre is extracted from these beds by lixiviating the earthy matters with water. This water, when sufficiently impregnated, is evaporated, and a brown-coloured salt obtained, known by the name of *crude nitre.* It consists of nitre, common salt, nitrate of lime, and various other salts. The foreign salts are either separated by repeated crystallizations, or by washing the salt repeatedly with small quantities of water; for the foreign salts being more soluble are taken up first.

Properties.

Nitre, when slowly evaporated, is obtained in six-sided prisms, terminated by six-sided pyramids; but for most purposes it is preferred in an irregular mass, because in that state it contains less water. The primitive form of its crystals, according to Haüy, is a rectangular octahedron, composed of two four-sided pyramids applied base to base; two of the sides are inclined to the other pyramid at the angle of 120°; at the other two at an angle of 111°. The form of its integrant particles is the tetrahedron. The six-sided prism is the most common form which it assumes. Sometimes, instead of six-sided pyramids, these prisms are terminated by 18 facets, disposed in three ranges of six, as if three truncated pyramids were piled on each other: sometimes it crystallizes in tables.[*]

The specific gravity of nitre, as ascertained by Dr. Watson, is 1·933.[†] Its taste is sharp, bitterish, and cooling. It is very brittle. It is soluble in seven times its weight of water at the temperature of 60°, and in rather less than its own weight of boiling water.[‡] It dissolves in 1·04 parts of water at the temperature 144°.[§] Alcohol, of the specific gravity ·878, dissolves $\frac{1}{100}$th of its weight of this salt, but stronger alcohol takes up no sensible portion of it.[||] It is not altered by exposure to the air.

When the solution of nitre is exposed to a boiling heat, part of the salt is evaporated along with the water, as Wallerius, Kirwan, and Lavoisier, observed successively. When exposed to a strong heat it melts, and congeals by cooling into an opaque mass, which has been called *mineral crystal.* When heated nearly to redness it begins to disengage oxygen; and by keeping it in a red heat, about the third of its weight of that gas may be obtained: towards the end of the process azotic gas is disengaged. If the heat be continued long

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[*] Traité de Mineralogie, ii. 346.

[†] Essays, v. 67. Wallerius makes it 1·900 (Chemistry, p. 266); Hassenfratz found it 1·9369 (Ann. de Chim. xxviii. 12.); Fahrenheit had stated it as long ago as 1724 at 2·150 (Phil. Trans. xxxiii. 114.)

[‡] Bergman, i. 134.

[§] Wenzel. p. 309.

[||] Kirwan.

enough, the salt is completely decomposed, and pure potash remains behind.

It detonates more violently with combustible bodies than any of the other nitrates. When mixed with one-third part of its weight of charcoal, and thrown into a red-hot crucible, or when charcoal is thrown into red-hot nitre, detonation takes place, and one of the most brilliant combustions that can be exhibited. The residuum is carbonate of potash. It was formerly called *nitre fixed by charcoal*. The alchymists performed this experiment in a tubulated earthen retort, to which an apparatus of glass vessels was luted. After every portion of nitre and charcoal which they threw in, they shut up the retort. The carbonic acid and azotic gas which were disengaged often burst their apparatus. To the small quantity of water which they obtained in their vessels, they gave the name of *clyssus*, and ascribed to it a great many virtues. A still more violent detonation is produced by using phosphorus instead of charcoal. When a mixture of nitre and phosphorus is struck smartly with a hot hammer, a very violent detonation is produced.*

Nitre oxidizes all the metals at a red heat, even gold and platinum.†

Composition.

The composition of nitre, according to the most exact analyses hitherto made, is as follows:

	‡	§	‖	**	††	‡‡	§§
Acid	45·92 ..	46·7 ..	51·36 ..	52 ..	53·54 ..	54·34 ..	52·95
Base	54·08 ..	53·3 ..	48·64 ..	48 ..	46·46 ..	45·66 ..	47·05
Total....	100	..100	..100	..100	..100	..100	..100

Gunpowder.

Nitre furnishes all the nitric acid in all its states employed either by chemists or artists. When burnt with tartar it yields a pure carbonate of potash. In the assaying of various ores it is indispensable, and is equally necessary in the analysis of many vegetable and animal substances. But one of the most important compounds formed by means of nitre is *gunpowder*, which has completely changed the modern art of war. The discoverer of this compound, and the person who first thought

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* Brugnatelli, Ann. de Chim. xxvii. 71.

† Tennant, Bergman, and Morveau.

‡ Kirwan, Nicholson's quarto Journal, iii. 215.

§ Richter, Statique Chimique, p. 136.

‖ Berard, Ann. de Chim. lxxi. 69.

** Wenzel's Verwandschaft, p. lxxx.

†† Wollaston.

‡‡ By my analysis.

§§ Theoretic composition.

of applying it to the purposes of war, are unknown. It is certain, however, that it was used in the 14th century. From certain archives quoted by Wiegleb, it appears that cannons were employed in Germany before the year 1372. No traces of it can be found in any European author previous to the 13th century; but it seems to have been known to the Chinese long before that period. There is reason to believe that cannons were used in the battle of Cressy, which was fought in 1346. They seem even to have been used three years earlier at the siege of Algesiras; but before this time they must have been known in Germany, as there is a piece of ordnance at Amberg, on which is inscribed the year 1303. Roger Bacon, who died in 1292, knew the properties of gunpowder; but it does not follow that he was acquainted with its application to fire-arms.*

Gunpowder is composed of nitre, sulphur, and charcoal, reduced to powder, and mixed intimately with each other. The proportion of the ingredients varies very considerably; but good gunpowder may be composed of the following proportions.†

Composition.

76	parts of nitre
15	charcoal
9	sulphur
100	

These ingredients are first reduced to a fine powder separately, then mixed intimately, and formed into a thick paste with water. After this has dried a little, it is placed upon a kind of sieve full of small holes, through which it is forced. By that process it is divided into grains, the size of which depends upon the size of the holes through which they have been squeezed. The powder, when dry, is put into barrels, which are made to turn round on their axes. By this motion the grains of gunpowder rub against each other, their asperities are worn off, and their surfaces are made smooth. The powder is then said to be glazed.

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* See Watson's Chemical Essays, vol. i. 327, for a full detail of the facts respecting this subject. From Barbour's life of Robert Bruce, it appears that guns were used by the English for the first time about the year 1320.

† For a full detail of every thing respecting the proportions and manufacture of gunpowder, the reader is referred to a very interesting dissertation by Dr. Watson, Essays, ii. 1, and to Baumé's Chemistry, i. 455.

Gunpowder, as is well known, explodes violently when a red heat is applied to it. This combustion takes place even in a vacuum; a vast quantity of gas is emitted, the sudden production of which is the cause of all the violent effects which this substance produces. The combustion is evidently owing to the decomposition of the nitre by the charcoal and sulphur. The products are carbonic acid gas, azotic gas, sulphurous acid gas, and probably sulphuretted hydrogen. Mr. Cruickshanks has ascertained that no perceptible quantity of water is formed. What remains after the combustion is potash combined with a small portion of carbonic acid, sulphate of potash, a very small proportion of sulphuret of potash, and unconsumed charcoal.* This mixture soon attracts moisture, and the sulphuret which it contains enables it to act strongly on metallic bodies.

Fulminating powder.

When three parts of nitre, two parts of potash, and one part of sulphur, all previously well dried, are mixed together in a warm mortar, the resulting compound is known by the name of *fulminating powder.* If a little of this powder be put into an iron spoon, and placed upon burning coals, or held above the flame of a candle, it gradually blackens, and at last melts. At that instant it explodes with a very violent report, and a strong impression is made upon the bottom of the spoon, as if it had been pressed down very violently. This sudden and violent combustion is occasioned by the rapid action of the sulphur on the nitre. By the application of the heat, the sulphur and potash form a sulphuret, which is combustible at a lower heat probably than even sulphur. Sulphuretted hydrogen gas, azotic gas, and perhaps also sulphurous acid gas, are disengaged almost instantaneously. It is to the sudden action of these on the surrounding air that the report is to be ascribed. Its loudness evidently depends upon the combustion of the whole powder at the same instant, which is secured by the previous fusion that it undergoes: whereas the grains of gunpowder burn in succession.

A mixture of equal parts of tartar and nitre, deflagrated in a crucible, is known by the name of *white flux.* It is merely a mixture of carbonate of potash with some pure potash. When two parts of tartar and one of nitre are deflagrated in this manner, the residuum is called *black flux* from its colour. It is merely a mixture of charcoal and carbonate of potash.

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* Cruickshanks, Nicholson's Journal, iv. 258.

Book II. Division II.

2. Nitrite.

Sp. 2. *Nitrite of potash.* Scheele's process for obtaining this salt is as follows: fill a small retort with nitre, and keep it red hot for half an hour. When it is allowed to cool, it is found in the state of a nitrite. It deliquesces when exposed to the air, and red vapours of nitrous acid are exhaled when any other acid is poured upon it.

3. Carbonate.

Sp. 3. *Carbonate of potash.* This salt has been long known to chemists; and before its composition was ascertained by Black, it was characterized by a great variety of names, according to the manner of preparing it; such as *fixed nitre*, *salt of tartar*, *vegetable alkali*, &c. Its properties were first described with precision by Bergman in 1774.[*] There are two subspecies of it; namely the carbonate and bicarbonate.

Preparation.

Subspecies 1. *Bicarbonate.* This salt is formed by saturating potash with carbonic acid, which is best done by causing the gas to pass through a solution of potash till it refuses to absorb any more. The potash of commerce is an impure carbonate of potash: by distilling it with solid carbonate of ammonia, it may be converted into bicarbonate of potash.[†] When potash is thus saturated with carbonic acid, it always lets fall a quantity of silica. Mr. Pelletier has proposed this saturation as the best method of purifying potash from the earth.

Properties.

It crystallizes, according to Bergman, in quadrangular prisms; the apexes of which are composed of two inverted triangles, converging like the roof of a house.[‡] According to Pelletier they are tetrahedral rhomboidal prisms, with dihedral summits. The complete crystal has eight faces, two hexagons, two rectangles, and four rhombs.[§] It has an alkaline, but not a caustic taste, and still gives a green colour to vegetable blues. Its specific gravity is 2·012.[||] It is soluble at the common temperature in about four times its weight of water.[**] Boiling water dissolves $\frac{5}{6}$ths of its weight.[††] Alcohol, even when hot, does not dissolve above $\frac{1}{1200}$th part of it. Pelletier has observed, that when the crystallized salt is dissolved in boiling water, bubbles of carbonic acid gas are emitted. It is not altered by exposure to the air. Heat deprives it of its water and part of its acid, but does not decompose it completely.

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[*] Opusc, i. 13.

[†] Berthollet.

[‡] Bergman, i. 13.

[§] Ann. de Chim. xv. 29.

[||] Hassenfratz, Ann. de Chim. xxviii. 12.

[**] Bergman, i. 13.

[††] Pelletier.

The constituents of this salt, according to the most accurate analyses hitherto made, are as follows:

	*	†	‡	§
Acid	43	43	46·19	47·83
Base	40	41	53·81	52·17
Water	17	16		
Total	100	100	100	100

The crystals of this salt contain just 1 atom of water, so that they consist of

Anhydrous salt	91·09
Water	8·91

Preparation.

Subspecies 2. *Carbonate.* The potash of commerce always occurs in this state; but its purity is destroyed by the mixture of foreign substances. Pure carbonate of potash may be procured by heating neutral bicarbonate, prepared by the process above described, to redness, in a silver or platinum vessel. A portion of the carbonic acid is driven off. The carbonate thus formed has a stronger alkaline taste, and acts with more energy on animal and vegetable substances, than the carbonate. When exposed to the air it soon deliquesces, and assumes the consistency of an oil. It does not absorb carbonic acid sensibly from the atmosphere; the excess of alkali cannot be removed by treating the salt with alcohol. Dr. Wollaston has shown that this salt contains exactly one half of the acid which exists in carbonate of potash.[||] Hence it is composed of

Carbonic acid	2·75	100
Potash	6·00	218·18

According to the experiments of Berard it appears that this salt, when gently dried so as to be solid, is composed of 1 atom anhydrous salt + 2 atoms water, or by weight of

Anhydrous salt	79·4
Water	20·6

Composition of potash of commerce.

The potash of commerce is always in the state of a carbonate; but it contains likewise several foreign substances which render

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[*] Kirwan, Nicholson's Quarto Jour. iii. 215.

[†] Pelletier, Ann. de Chim. xv. 33.

[‡] Berard, Ann. de Chim. lxxi. 69.

[§] Theoretic composition.

[||] Wollaston, on superacid and subacid Salts, Phil. Trans. 1808.

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the proportion of alkali variable. Mr. Kirwan has pointed out a very ingenious method of detecting the quantity of alkali in any specimen, by the property which it has of precipitating alumina from alum; and Vauquelin has published a still simpler method, namely, the quantity of nitric acid of a given density necessary to saturate a given weight of the salt. From his experiments, we learn that the following kinds of this salt known in commerce contain the following ingredients.*

	Potash.	Sulphate of potash.	Muriate of potash.	Insoluble residue.	Carbonic acid and water.	Total.
Potash of Russia	772	65	5	56	254	1152
——— America	857	154	20	2	119	1152
American Pearl-ash	754	80	4	6	308	1152
Potash of Treves	720	165	44	24	199	1152
——— Dantzic.	603	152	14	79	304	1152
——— Vosges	444	148	510	34	304	1440

4. Borate.

Sp. 4. *Borate of potash.* This salt, which was first formed by Baron, is very little known. It may be prepared by calcining a mixture of boracic acid and nitre. The heat drives off the nitric acid, and leaves a white saline mass, which, when dissolved in water, yields crystals of borate of potash in four-sided prisms. It is capable of combining with an excess of base, and forming a sub-borate of potash. From the experiments of Wenzel, the proportion of its constituents seems to be†

Acid	100
Base	30

The constituents of pure borate of potash ought to be

Boracic acid	2·875	100
Potash	6	208·5

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* Ann. de Chim. xl. 273

† Verwandtschaft, p. 228.

The constituents of biborate of potash should be

Boracic acid	2·875 × 2	100
Potash	6	104·25

Hence it is obvious that Wenzel's analysis is very erroneous. Berzelius attempted to determine the constituents of this salt experimentally, but could not succeed.

5. Silicate.

Sp. 5. *Silicate of potash.* This is the compound known to chemists by the name of *liquor silicum.* It may be formed by fusing three parts of potash by weight with one part of silica. A transparent colourless liquid is formed, which on cooling congeals into glass. This glass is soluble in water, and the colourless solution is called *liquor silicum.*

Silica seems capable of uniting with potash in a great number of proportions. Glass may be considered as a supersilicate of potash, in which the proportion of silica is very considerable.

6. Phosphate.

Sp. 6. *Phosphate of potash.* Of this salt there are three subspecies, namely, the *phosphate*, the *biphosphate*, and *subphosphate of potash.*

Subspecies 1. *Phosphate of potash.* This salt may be obtained by adding carbonate of potash to hot phosphoric acid, till the solution ceases to produce any effect upon vegetable blues. When this solution is sufficiently concentrated, and set aside in a dry place it gradually deposites phosphate of potash in small transparent crystals. These crystals are four-sided prisms terminated by four-sided pyramids. The sides of the prism are all equal, and its angles right angles. Sometimes the intervening prism is wanting so that the crystals have the form of small octahedrons. This salt has a cooling and somewhat urinous taste, but neither strong nor disagreeable. It is not altered by exposure to the air, and contains no water of crystallization. It is very soluble in water, and melts into a liquid when exposed to a red heat.

Subspecies 2. *Biphosphate.* This salt is easily formed by dissolving the neutral phosphate in phosphoric acid till the liquid is saturated. It crystallizes with great difficulty into striated prisms; assuming more readily the form of a jelly, and when the evaporation is carried farther, becoming dry altogether. Its specific gravity, when dry, is 2·8516.[*] It is exceedingly soluble in water; and when dry readily attracts

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[*] Hassenfratz. Ann. de Chim. xxviii. 12.

moisture from the atmosphere, and is converted into a viscid liquid. When heated, it first undergoes the watery fusion; then allows its water of crystallization to evaporate, and is reduced to dryness. In a high temperature it melts into a transparent glass, which deliquesces again when exposed to the air.

Subspecies 3. *Subphosphate.* This salt may be formed by mixing together phosphate of potash and pure potash, and exposing them to a strong heat in a platinum crucible. A white coloured substance is obtained, which is the phosphate in question. Or we may boil any of the alkaline superphosphates in a solution of potash. A white powder falls, which is the salt wanted. By this last process it was procured by Margraff.

The phosphate of potash is tasteless and insoluble in cold water, but soluble in hot water; and it precipitates as the solution cools in a gritty powder. It is extremely fusible; melting before the blow-pipe into a transparent bead, which becomes opaque on cooling. It is soluble in nitric, muriatic, and phosphoric acids: the solutions are thick, glutinous, and adhesive. When sufficiently diluted, the alkalies occasion no precipitate in these solutions; but when they are concentrated, a precipitate appears.

According to the analysis of Saussure, junior, its composition is as follows:

acid	35
base	65
	100[*]

This salt has the property of combining, and of forming a triple insoluble compound with lime.

Sp. 7. *Phosphite of potash.* This salt has not hitherto been examined in a state of purity.

8. Hypophosphite.

Sp. 8. *Hypophosphite of potash.* This salt is exceedingly soluble in water. It is more deliquescent than muriate of lime. It dissolves in alcohol in all proportions. When exposed to the air it gradually absorbs oxygen and becomes acid. When heated, phosphuretted hydrogen gas and some phosphorus are given out, and a quantity of phosphoric acid united to potash remains behind.[†]

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[*] Sur la Vegete, p. 321.

[†] Dulong, Ann. de Chim. et de Phys. ii. 142.

9. Sulphate.

Sp. 9. *Sulphate of potash.* Of this salt there are two subspecies. The first is neutral, the second is a bisulphate.

Subspecies 1. *Sulphate.* This salt may be formed by saturating diluted potash with sulphuric acid, and then evaporating the solution gently till crystals appear. It seems to have been known at a very early period by chemists, and a great variety of names are given to it, according to the manner of forming it, or the fancy of the operator. Some of these names were, *specificum purgans*, *nitrum fixum*, *arcanum duplicatum*, *panacea holsatica*, *sal de duobus*, *sal polychrest glaseri*, &c.; but it was commonly known by the name of *vitriolated tartar*, till the French chemists called it *sulphate of potash*, when they formed their new nomenclature in 1787.*

Names.

Sulphate of potash, or perhaps the bisulphate, was discovered by examining what remained in the retort after the preparation of nitric acid, by distilling a mixture of sulphuric acid and nitre. It was the salt obtained from this residuum that was called *panacea duplicata*, or *arcanum duplicatum.* The Duke of Holstein, sometime before the year 1663, purchased the preparation of this salt for 500 dollars as a remedy in fevers, stone, and scurvy.†

Properties.

When the solution of sulphate of potash is sufficiently diluted, it affords by evaporation hexahedral pyramids, or short hexangular prisms, terminated by one or more hexangular pyramids. But these crystals vary much in their figure, according to the care with which they are prepared.

It has a very disagreeable bitter taste. Its specific gravity, according to Wallerius,‡ is 2·298; according to Hassenfratz, 2·4073; § according to Watson, 2·636. || At the temperature of 60° it dissolves in 16 times its weight of water: in a boiling heat it is soluble in five times its weight.** When it is boiled in water, that liquid dissolves 0·242 parts, or nearly ¼th of its weight of it.††

It suffers no alteration when exposed to the air. When placed upon burning coals, it decrepitates, but suffers no other alteration. In a red heat it melts, and loses 1½ *per cent.*

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* Bergman called it alkali vegetabile vitriolatum, and Morveau vitriol of potash.

† Shaw's Boyle, i. 64.

‡ Chemistry, p. 265.

§ Ann. de Chim. xxviii. 12.

|| Chemical Essays, v. 67.

** Bergman, i. 135.

†† Wenzel's Verwandschaft, p. 310.

of its weight. It is sometimes luminous in the dark, as Mr. Giobert has observed.*

Constituents.

Its component parts, according to the best analyses hitherto published, are as follows:

	†	‡	§	||	**	††
Acid	42·76	.. 45·2	.. 45·3	.. 45·72	.. 47·1	.. 45·46
Base	57·24	.. 54·8	.. 54·7	.. 54·28	.. 52·9	.. 54·54
	100·00	100·0	100·0	100·00	100·0	100·00

It contains no water of crystallization.

Subspecies 2. *Bisulphate.* This salt may be prepared by heating together a mixture of 3 parts of sulphate of potash and 1 part of sulphuric acid. It was first distinguished from the first variety by Rouelle senior.

It usually crystallizes in long slender needles, but it may be obtained in six-sided prisms. Its taste is acrid, and it reddens vegetable blues. It is soluble in five parts of water at the temperature of 60°.‡‡ It is scarcely altered by exposure to the air. When heated it melts readily and assumes the appearance of oil, but it becomes as white as ever when allowed to cool. A very violent and long continued heat dissipates the excess of acid, and converts it into sulphate. Dr. Wollaston has shown, that this salt contains just twice as much acid as the *sulphate.* §§

Sp. 10. *Ammonio-sulphate of potash.* This salt, which was first described by Link, may be formed by saturating the supersulphate of potash with ammonia. The crystals are brilliant plates, having a bitter taste, and not altered by exposure to the air. They are composed of

60	sulphate of potash
40	sulphate of ammonia
100 ||||	

11. Sulphite.

Sp. 11. *Sulphite of potash.* This salt was formed by Stahl, but was first accurately described by Berthollet, Fourcroy, and

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* Ann. de Chim. x. 40.

† Berard, Ann. de Chim. lxxi. 47.

‡ Kirwan, Nicholson's 4to Journal, iii. 215.

§ Wenzel, Verwandtschaft, p. 54.

|| By my analysis.

** Berzelius, Ann. de Chim. lxxvii. 84.

†† Theoretic composition.

‡‡ Link, Crell's Annals, 1796, i. 26.

§§ On superacid and subacid salts. Phil. Trans. 1808.

|||| Link, Crell's Annals, 1796, i. 29.

Vauquelin. It was formerly known by the name of *sulphureous salt of Stahl*. It may be formed by passing sulphurous acid into a saturated solution of carbonate of potash till all effervescence ceases. The solution becomes hot, and crystallizes by cooling.*

Properties.

Its crystals are white and transparent: their figure, that of rhomboidal plates. Its crystallization often presents small needles diverging from a common centre.† Its specific gravity is 1·586.‡ Its taste is penetrating and sulphureous. At the common temperature of the atmosphere it is soluble in its own weight of water, but much more soluble in boiling water. When exposed to the air, it scarcely changes its appearance, loses about 2 per cent. of its weight, and then is gradually, but very slowly, converted into sulphate of potash. When exposed to a sudden heat, it decrepitates, loses its water and a portion of its acid; then a quantity of sulphur is disengaged from the remaining acid, and the residuum is sulphate of potash, with a slight excess of alkali. Nitric acid converts it into sulphate of potash by imparting oxygen. So does chlorine, but imperfectly, as it drives off a portion of its acid unchanged.

It decomposes the oxides of gold, silver, mercury, the red oxide of lead, the black oxide of manganese, and the brown oxide of iron. When the green hydrate of iron, or the white oxide of arsenic, is boiled with it in water, and an acid added, a precipitate takes place, consisting of these oxides united to some sulphur, and the salt is converted into a sulphate; at the same time sulphuretted hydrogen gas is emitted. It is composed of

Sulphurous acid	4	40	100
Potash	6	60	150

Sp. 12. *Hyposulphite of potash.* This salt is easily formed by exposing hydroguretted sulphuret of potash to the atmosphere till it loses its yellow colour. The liquid is then a solution of hyposulphite of potash. When sufficiently concentrated it crystallizes in a confused mass of spiculæ. It has a penetrating taste like nitre, succeeded by a bitterness, and is very deliquescent. The deliquiated salt crystallizes in fine needles by a slight diminution of temperature. By the

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* Fourcroy and Vauquelin, Nicholson's Journal, i. 317.

† Ibid.

‡ Hassenfratz, Ann. de Chim. xxviii. 12.

action of a graduated heat it boils down to a dry white mass, then takes fire and burns much like a piece of tinder, but with a weak blue flame. It dissolves chloride of silver, even when very dilute, with great readiness.*

Sp. 13. *Hyposulphate of potash* crystallizes in cylindroidal prisms, terminated by a plate perpendicular to their axis.†

Sp. 14. *Seleniate of potash.* Potash combines with three proportions of selenic acid, forming neutral *seleniate, biseleniate,* and *quadriseleniate.*

(1.) *Seleniate* of potash is exceedingly soluble in water. When concentrated sufficiently, the surface becomes covered with a crystalline pellicle. When evaporated to dryness, the salt attracts moisture from the atmosphere. At a red heat it melts and becomes yellow; but recovers its white colour on cooling. It is insoluble in alcohol.

(2.) *Biseleniate* of potash crystallizes (with difficulty) when sufficiently concentrated. The crystals are feather-shaped. It deliquesces when exposed to the air and dissolves in a small proportion in alcohol. When long exposed to heat, one half of the acid is driven off and it is reduced to neutral seleniate.

(3.) The *quadriseleniate* of potash does not crystallize, and when evaporated to dryness speedily deliquesces again.‡

Sp. 15. *Arseniate of potash.* Of this salt there are two subspecies, the *arseniate* and the *sub-binarseniate.*

(1.) *Arseniate.* This salt was first formed by Macquer; and for that reason was long distinguished by the name of *arsenical neutral salt of Macquer.* He obtained it by distilling in a retort a mixture, consisting of equal parts of white oxide of arsenic and nitre. After the distillation, the white saline mass, which remained in the retort, was dissolved in hot water and filtered. When properly evaporated, beautiful transparent crystals of arseniate of potash are obtained.§

Scheele first ascertained the composition of this salt, by discovering that it was obtained by adding arsenic acid to the sub-binarseniate of potash till the solution ceases to alter the colour of syrup of violets. It then reddens the infusion of turnsole, and yields by evaporation fine crystals of Macquer's neutral salt.

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* Herschell; Edin. Phil. Jour. i. 19.

† Annals of Philosophy, xiv. 355.

‡ Berzelius; Ann. de Chim. et de Phys. ix. 257.

§ Mem. Par. 1746, p. 223.

This salt is white and transparent, and crytallizes in four-sided rectangular prisms, terminated by very long four-sided pyramids. It has a saline and cooling taste, somewhat similar to that of nitre. It is not altered by exposure to the air. Specific gravity 2·638. It may be kept in a heat of 550° for a considerable time without melting or undergoing any sensible change. In a red heat it melts and becomes as liquid as water. The congealed salt is opaque or only translucent. By this treatment it loses 7·5 per cent. of its weight.

It is insoluble in alcohol. 100 parts of water at the temperature of 42 dissolve 19·047 parts of the salt. The specific gravity of this solution (at 60°) is 1·1134. It is much more soluble in hot than in cold water. Hence a saturated solution in hot water crystallizes very readily on cooling. The constituents of this salt, by my analysis, are as follows:

Arsenic acid	65·426	14·5
Potash	27·074	6·0
Water	7·500	1·6875
	100·000	

or 1 atom acid + 1 atom potash + 1½ atom water.*

(2.) *Sub-binarseniate.* When arsenic acid is supersaturated with potash, it forms an incrystallizable salt, which deliquesces in the air, renders syrup of violets green, but does not alter the infusion of turnsole. When heated in a clay crucible, it is partly converted into a white glass, and partly changed into arseniate of potash. When mixed with one-eighth of its weight of charcoal powder, and distilled in a retort, it swells and bubbles up violently, evidently in consequence of the disengagement of carbonic acid gas, and at the same time a quantity of arsenic is sublimed: the residuum is merely carbonate of potash and charcoal.

Sp. 16. *Arsenite of potash.* A yellow viscid liquid which does not crystallize. Formed by saturating potash solution with arseneous acid.

17. Antimoniate.

Sp. 17. *Antimoniate of potash.* This salt may be obtained by exposing a mixture of 1 part of powdered antimony and 6 parts of nitre to the greatest heat which it can bear without fusion. It is then to be reduced to powder and washed with cold water till all the alkali and nitre are dissolved. The an-

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* Annals of Philosophy, xv. 85.

timoniate of potash now remains. It is a white powder having an acrid and slightly metallic taste. It is scarcely soluble in cold water, but 'dissolves readily in boiling water. This solution lets fall nothing on cooling. When evaporated to the consistency of a syrup, it deposites a white granular and very light powder. If the liquid be evaporated to the consistence of honey the whole congeals during cooling into a semitransparent pliable crust. When evaporated to dryness it leaves a white enamel, which is brittle and cracked in every direction. This salt contains $11\frac{1}{2}$ per cent. of water. It is very difficult to decompose it. According to the experiments of Berzelius it is composed of

Antimonic acid	79·2	100
Potash	20·8	26

From this analysis it follows that the salt is a tritantimoniate, or a compound of 3 atoms acid with 1 atom potash.*

Sp. 18. *Antimonite of potash.* Berzelius formed this salt by fusing together white oxide of antimony and caustic potash. He then washed off the potash by means of cold water, and dissolved the powder that remained in boiling water. This water when evaporated yields the salt in a state of purity. Its properties are very similar to those of antimoniate of potash. According to the analysis of Berzelius, it is composed of

Antimonious acid	76·6	100
Potash	23·4	30·55

This agrees nearly with the supposition, that it is a compound of 1 atom acid + 1 atom potash, if the weight of an atom of antimonious acid be 20·875, as we have found it to be.†

19. Chromate. Sp. 19. *Chromate of potash.* This salt has hitherto been examined only by Vauquelin ‡ and John. § There are two subspecies of it. 1. The neutral chromate, of a lemon yellow colour, which crystallizes in flat four-sided prisms gradually tapering to a point. I find that it precipitates

Pernitrate of mercury	yellow
Nitrate of silver	brick-red
Nitrate of copper	pea-green

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* Berzelius, Nicholson's Journal, xxxv. 38. † Ibid. 44.

‡ Ann. de Chim. lxx. 70.

§ Annals of Philosophy, iv. 125.

2. The bichromate, which is a beautiful orange-red crystalline powder. It is not nearly so soluble in water as the chromate.

20. Molybdate.

Sp. 20. *Molybdate of potash.* This salt may be formed either by uniting directly its acid and base, or by heating two parts of nitre and one of molybdic acid in a crucible, and lixiviating the mass obtained. The solution crystallizes by evaporation in small rhomboidal plates inserted into each other. They are bright, and have a metallic taste. When exposed to the blow-pipe upon charcoal, they melt without swelling, and are converted into small globules, which are quickly absorbed by the charcoal. When melted with a mixture of phosphate of soda and of ammonia (or microcosmic salt), they communicate a green tinge. Hot water dissolves them completely, and prussiate of potash occasions in this solution a reddish brown precipitate.* All the strong acids precipitate the molybdic acid from solutions of this salt.

21. Tungstate.

Sp. 21. *Tungstate of potash.* This salt may be formed by dissolving oxide of tungsten in the solution of potash or carbonate of potash. The solution always retains an excess of potash, refusing to dissolve the oxide before the alkali be completely neutralized. By evaporation the tungstate of potash precipitates in the state of a white powder.

This salt has a metallic and caustic taste; it is soluble in water, and very soon deliquesces when exposed to the air. Its solution in water is decomposed by all the acids: they occasion a precipitate composed of the oxide, potash, and the acid employed. This precipitate or triple salt is the molybdic acid of Scheele.†

Sp. 22. *Nitro-tungstate of potash.* These tungstates are capable of combining with a number of acids, and forming with them a particular kind of neutral salts which have not been particularly examined, if we except *nitrated tungstate of potash*, which is the salt originally described by Scheele under the name of *acid of tungsten.*

This salt is obtained in the form of a white powder; it has an acid and bitter taste, reddens the infusion of turnsole, and is soluble in 20 parts of boiling water. The De Luyarts first showed it to be a compound of nitric acid, oxide of tungsten, and potash.

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* Klaproth, Ann. de Chim. xlii. 106.

† Vauquelin and Hecht, Jour. de Min. No. 19, p. 20.

23. Columbate. Sp. 23. *Columbate of potash.* When columbic acid is boiled in a solution of potash, a portion of it is dissolved, and the solution yields by evaporation a white glittering salt in scales, very much resembling boracic acid. Its taste is acrid and disagreeable. It is not altered by exposure to the air. Cold water dissolves it sparingly; but the solution is colourless and permanent. The acid is precipitated by nitric acid, and other acids, in the state of a white powder.*

24. Acetate. Sp. 24. *Acetate of potash.* Pliny is supposed, but probably without any reason, to have been acquainted with this salt, because he recommends a mixture of vinegar and vine-ashes as a cure for a particular species of tumor.† It was first clearly described by Raymond Lully. It has received a great number of names; as, for instance, *arcanum tartari, secret foliated earth of tartar, essential salt of wine, regenerated tartar, diuretic salt, digestive salt of Sylvius.* It is usually formed by dissolving carbonate of potash in distilled vinegar, and evaporating the solution to dryness in a moderate heat. The solution when concentrated ought to be filtered through animal charcoal, provided distilled vinegar has been employed in its preparation.‡ By this process it is obtained in fine white plates. By a well managed evaporation it may be procured in regular prismatic crystals. This salt has a sharp warm taste. At the temperature of 60°, 100 parts of it are soluble in 102 parts of water.§ It is soluble also in alcohol. When exposed to the air, it deliquesces rapidly. When heated, it readily melts, and in a high temperature its acid is decomposed. A liquid passes over into the receiver, which sometimes contains a considerable portion of ammonia and prussic acid. What remains in the retort consists of charcoal mixed with the carbonates and prussiates of potash.‖ The presence of ammonia and prussic acid in the products of distillation of this salt led Proust to consider azote as one of the constituents of acetic acid. But Trommsdorf and Proust himself have since shown that pure acetate of potash yields neither ammonia nor prussic acid.** When distilled along with white oxide of arsenic, it yields,

Products of distillation.

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* Hatchett's Analysis of a Mineral from North America. Phil. Trans. 1802.

† Plinii, lib. xxiii. procemium.

‡ Fequier, Ann. de Chim. lxxxvi. 44.

§ Speilmann.

‖ Proust, Ann. de Chim. xlii. 231.

** Ann. de Chim. lxi. 111.

according to Cadet, a white smoke, which has an odour intolerably offensive, and takes fire when it comes into contact with the air. Chap. II.

The following table exhibits the constituents of this salt according to the experiments hitherto made:

Composition.

	*	†	‡	§
Acid	38·5	47·98	49·85	51·52
Base	61·5	52·02	50·15	48·48
Total	100·0	100·00	100·00	100·00

25. Benzoate. Sp. 25. *Benzoate of potash.* There are two subspecies of this salt. 1. Neutral benzoate which crystallizes in feather-shaped crystals. It has a sharp saline taste, is very soluble in water, and deliquesces when exposed to the air. 2. Bibenzoate. It crystallizes in small plates and needles, which require ten times their weight of cold water to dissolve them. It reddens vegetable blues, and has an acid and sweetish taste. When heated to redness part of the acid sublimes without decomposition, but part likewise is destroyed. An empyreumatic oil is formed, and some charcoal remains mixed with carbonate of potash.||

26. Succinate. Sp. 26. *Succinate of potash.* This salt, according to Leonhardi and Stockar, crystallizes in three-sided prisms. It has a bitter saline taste, is very soluble in water, and deliquesces when exposed to the air. When exposed to heat, it decrepitates and melts; and in a strong heat is decomposed.

27. Camphorate. Sp. 27. *Camphorate of potash.* To prepare this salt, carbonate of potash is to be dissolved in water, and the solution saturated with camphoric acid. When the effervescence is over, the liquor is to be evaporated by a gentle heat to the proper consistence, and crystals of camphorate of potash will be deposited when the liquor cools. Camphorate of potash is white and transparent; its crystals are regular hexagons. Its taste is bitterish and slightly aromatic.

Water at the temperature of 60° dissolves $\frac{1}{100}$th part of its weight of this salt; boiling water dissolves $\frac{1}{4}$th part of its weight. It is soluble in alcohol, and the solution burns with

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* Higgins On Acetous Acid, p. 8.

† Richter, Statique Chimique, i. 136.

‡ Wenzel, Verwandtschaft, p. 147. § Theoretic composition.

|| Bucholz, Ann. de Chim. lxxxiv. 311.

a deep blue flame. When exposed to a moist air, it loses a little of its transparency; but in dry air it suffers no change. When exposed to heat it melts, swells, and the acid is volatilized in a thick smoke, which has an aromatic odour. Before the blow-pipe it burns with a blue flame, and the potash remains behind in a state of purity.*

28. Suberate.

Sp. 28. *Boletate of potash.* Described in p. 157 of this vol.

Sp. 29. *Suberate of potash.* This salt ought to be formed by means of crystallized carbonate of potash. It crystallizes in prisms, having four unequal sides. It has a bitter saltish taste, and it reddens vegetable blues. It is very soluble in water. Heat melts it, and at last volatilizes the acid.†

30. Oxalate.

Sp. 30. *Oxalate of potash.* Of this salt there are three subspecies, the *oxalate*, *binoxalate*, and *quadroxalate.*

Subspecies 1. *Oxalate.* This salt is easily formed by dissolving potash in oxalic acid; but the solution does not readily crystallize unless there be a slight excess either of the acid or the base. A solution, composed of two parts of carbonate of potash, dissolved in one part of acid, yields six-sided prisms, not unlike the crystals of oxalic acid. These crystals fail to powder when heated. They give a green tinge to litmus paper, but they redden tincture of litmus and syrup of violets.‡

When neutral, this salt crystallizes in flat, oblique four-sided prisms, commonly terminated by dihedral summits; the lateral edges of the prism are usually bevelled. Its taste is cooling and bitter. At the temperature of 50°, 100 water dissolve 45 of salt. When dried on the sand bath, and afterwards exposed in a damp place, it absorbs a little moisture from the atmosphere.

Subspecies 2. *Binoxalate.* This salt exists ready formed in *oxalis acetosella*, or wood-sorrel, and in the *rumex acetosa;* from which it is extracted in some parts of Europe in great quantities. Hence it is known by the name of *salt of wood-sorrel*, and in this country is sold under the name of *essential salt of lemons.* It is mentioned by Duclos in the Memoirs of the French Academy for 1668. Margraff first proved that it contained potash; and Scheele discovered its acid to be the oxalic. A great many interesting experiments had been previously made on it by Wenzel and Wiegleb.

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* Bouillon Lagrange, Ann. de Chim. xxvii. 24.

† Ann. de Chim. xxiii. 52.

‡ Bergman, i. 260.

It may be formed, as Scheele has shown, by dropping potash very gradually into a saturated solution of oxalic acid in water: as soon as the proper quantity of alkali is added, the binoxalate is precipitated. But care must be taken not to add too much alkali, otherwise no precipitation will take place at all.* Its crystals are small white parallelopipeds;† or rather rhomboids approaching cubes. It has an acid, pungent, bitterish taste. It is soluble in about ten times its weight of boiling water, but much less soluble in cold water. It is not altered by exposure to the air. Heat decomposes it. The salt is capable of combining with most of the alkalies and earths, and of forming with them triple salts which have not been accurately examined. Dr. Wollaston has shown that it contains exactly double the proportion of acid which oxalate of potash contains.‡

Subspecies 3. *Quadroxalate.* This subspecies was discovered by Dr. Wollaston. When nitric or muriatic acids are made to act upon binoxalate of potash, they deprive it of one half of its alkali. There remains behind an oxalate containing exactly four times the proportion of acid that exists in oxalate of potash. Hence the name given it by Dr. Wollaston. This salt may be purified by a second crystallization. Its crystals are octahedrons having both their apexes truncated pretty deeply. If three parts of it be decomposed by a red heat, and the alkali thus evolved be added to 1 part of the quadroxalate, it will just convert it into a neutral oxalate.§

Oxalate of potash ought to be composed of

Oxalic acid	4·5	100
Potash	6	133·33

In my analysis I obtained 100 acid + 122·86 potash. But the acid which I used contained some water, which destroyed the accuracy of the conclusions. Berard's analysis is much more erroneous than mine.|| Vogel of Bayreuth obtained

Acid	100
Base	132·55

which is very near the truth.**

Of these three subspecies the quadroxalate is by far the most beautiful. Both it and the binoxalate crystallize very readily.

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* Crell's Annals, i. 107. Eng. Transl.

† Romé de Lisle.

‡ By the analysis of Vogel of Bareuth, it contains 12·63 per cent. of water. The crystals, therefore, are composed of 1 atom anhydrous binoxalate and 2 atoms water.

§ Wollaston, on superacid and subacid salts. Phil. Trans. 1808.

|| Ann. de Chim. lxxiii. 269.

** Annals of Philosophy, v. 30.

29. Mellate. Sp. 31. *Mellate of potash.* When mellitic acid is neutralized by potash, the solution crystallizes in long prisms.* The acid appears capable of combining with this salt, and forming a supermellate of potash: for when the *mellite* (or native mellate of alumina) is decomposed by carbonate of potash, and the alkaline solutions mixed with nitric acid, crystals are obtained, consisting of mellitic acid combined with a small portion of potash.†

30. Tartrate. Sp. 32. *Tartrate of potash.* Of this salt there are two subspecies. The first, which contains 2 atoms acid to one of potash is usually called *tartar;* the second, which is neutral, was formerly distinguished by the name of *soluble tartar*, because it is much more soluble in water than the first variety.

Subspecies 1. *Bitartrate of potash.* This salt is obtained, in a state of impurity, incrusted on the bottom and sides of casks in which wine has been kept. It is afterwards purified by dissolving it in boiling water, and filtering it while hot. On cooling, it deposites the pure salt in very irregular crystals. History. In this state it is sold under the name of *crystals* or *cream of tartar.* This salt attracted the peculiar attention of chemists, probably in consequence of the extravagant encomiums and invectives bestowed on it by Paracelsus. It is called *tartar*, says he, because it produces the oil, water, tincture, and salt, which burns the patient as *hell* does. According to him, it is the principle of every disease and every remedy, and all things contain the germ of it. This ridiculous theory was combated by Van Helmont, who gives a pretty accurate account of the formation of tartar in wine casks.‡ It was known to Van Helmont, and even to his predecessors, that potash could be obtained from tartar; but it was long a disputed point among chemists, whether that alkali existed in it ready formed. Duhamel, Margraff, and Rouelle, at last established that point beyond a doubt; but the other component part of tartar was unknown, or very imperfectly known, till Scheele pointed out the method of extracting it.

The crystals of tartar are very small and irregular. According to Monnet, they are prisms, somewhat flat, and mostly with six sides. Dr. Wollaston, to whom I gave some pretty large fragments of crystals of tartar, was good enough to in-

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* Klaproth's Beitrage, iii. 131.

† Vauquelin, Ann. de Chim. xxxvi. 209.

‡ Tartari Vini Historia, Van Helmont, p. 224.

vestigate the primitive form of the crystals of this very difficult salt. He considers it as a prism, the section of which is a rectangle, having its sides nearly as 8 to 11, terminated at each end by dihedral summits placed transversely, so that the sides of one summit meet in one diagonal and the sides of the opposite meet in the other at angles of 79½°. This constitutes a form to which all the modifications of the salt may be referred, and from which they may be calculated. If we conceive the sides of this prism shortened till they are reduced to nothing, the summits will then form a scalene tetrahedron, the sides of which are four similar triangles inclined to one another at angles of 79½°, 77°, and 53½°. If this tetrahedron be moved in the direction of its shortest diagonal, it describes the first prism, and the splits of that prism are the planes described by all the edges of the tetrahedron.

Properties.

Tartar has an acid, and rather unpleasant taste. It is very brittle, and easily reduced to powder. Its specific gravity is 1·953.* It is soluble in about 60 parts of cold water. When boiled in water, the liquid takes up nearly $\frac{1}{14}$th part of the salt.† It is not altered by exposure to the air; but when its solution in water is allowed to remain for some time, the salt is gradually decomposed, a mucous matter is deposited, and there remains in solution carbonate of potash coloured with a little oil. This decomposition was first accurately described by Berthollet in 1782.‡

When tartar is heated, it melts, swells, blackens, and the acid is entirely decomposed. The same changes take place when the salt is distilled in close vessels. The phenomena of this distillation have been described with great care, and its products very attentively examined by chemists; because, before the discovery of the tartaric acid by Scheele, distillation was the only method thought of for obtaining any knowledge of the acid part of tartar. These products are an enormous quantity of gas, consisting of carbonic acid and carburetted hydrogen, an oil, and an acid; and, according to some chemists, *carbonate of ammonia.* The acid obtained is called *pyrotartaric acid.*

Pyro-tartaric acid.

The tartar of commerce is never quite pure. All the specimens which I had an opportunity of examining contained rather more than 5 per cent. of tartrate of lime. A number of

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Wenzel, Verwandtschaft, p. 311.

‡ Mem. Par.

Book II. Division II.

specimens were examined by Vauquelin and Boullay; they found the tartrate of lime to vary from 5 to 6 per cent.*

Subspecies 2. *Tartrate of potash.* This salt is usually prepared by adding at intervals tartar in powder to a hot solution of carbonate of potash till all effervescence ceases. The solution is then boiled for some time, and afterwards evaporated till a pellicle forms on its surface. On cooling, the tartrate of potash crystallizes in flat four-sided rectangular prisms, terminated by dihedral summits. This salt has an unpleasant bitter taste. Its specific gravity is 1·5567.† According to Wenzel, it is soluble in its own weight of water at the temperature of 50°, and still more soluble in hot water.‡ When heated it melts, swells up, blackens, and is decomposed. It contains just half the proportion of acid which exists in tartar. The composition of this salt, according to the most accurate analyses hitherto made, is as follows:

	§	‖	**
Acid	58	58·69	58·27
Base	42	41·31	41·73
	100	100·00	100·00

Sp. 33. *Tartrate of potash-and-ammonia.* This triple salt may be formed by pouring ammonia into supertartrate of potash. Its crystals, according to Macquer, are prisms with four, five, or six sides: according to the Dijon academicians, parallelopipeds, with two alternate sloping sides.

It has a cooling taste. It is soluble enough in water. It effloresces in the air. Heat decomposes it.

Sp. 34. *Citrate of potash.* This salt may be formed by dissolving carbonate of potash in citric acid, and evaporating the solution to the requisite consistency. It is very soluble in water; does not crystallize easily; and readily deliquesces when exposed to the air. It is composed, according to Vauquelin, of

55·55	acid
44·45	potash
100·00††	

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* Ann. de Chim. lxii. 41.

† Hassenfratz, Ann. de Chim. xxviii. 12.

‡ Verwandtschaft, p. 308.

§ By my analysis.

‖ Berzelius, Ann. de Chim. lxxxii. 30.

** Theoretic composition.

†† Fourcroy, vii. 207.

Its true composition is

Acid	55·13
Base	44·87
	100·00

which agrees very well with the analysis of Vauquelin.

This salt, or rather its solution in water, is often employed in this country as a medicine to allay sickness, and put a stop to vomiting.

Sp. 35. *Kinate of potash.* Unknown.

Sp. 36. *Saclactate of potash.* Small crystals soluble in eight times their weight of boiling water.*

Sp. 37. *Urate of potash.* A white powder nearly similar to uric acid in appearance and solubility. It is soluble in potash ley.

Sp. 38. *Laccate of potash.* Unknown.

Sp. 39. *Malate of potash.* A deliquescent and a very soluble salt. It does not crystallize. The bimalate forms permanent crystals soluble in water, but insoluble in alcohol.†

40. Lactate.

Sp. 40. *Lactate of potash.* This salt may be obtained by adding lactate of lime to a warm solution of carbonate of potash till the alkali is saturated. It forms when evaporated to dryness a gummy, yellowish brown, transparent mass, which cannot easily be made hard. It dissolves readily when pure in hot alcohol. When sulphuric acid is poured upon this salt, no smell of acetic acid is given out; but when heat is applied to the mixture a disagreeable pungent smell may be perceived. The smell is observed when sulphuric acid is heated with any animal substance.‡

The composition of the salts of potash may be determined by conceiving them to consist of an atom of potash united to an atom of each of the acids. Potash weighs 6, and the weight of the acids has been given in a preceding part of this volume. In the bisalts the potash is united with two atoms of acid. In the subsalts an atom of acid is united to two atoms of potash.

Of all the salts of potash the most useful are the carbonate, the nitrate, and the tartrate.

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* Scheele on Sugar of Milk.

† Donovan.

‡ Berzelius, Djurkemien, ii. 435.

SECT. III.

SALTS OF SODA.

Book II. Division II. General properties.

1. In general the salts of soda are much more soluble in water than the salts of potash. Many of the salts of potash contain no water of crystallization, but most of the salts of soda contain a great deal.

2. When exposed to a red heat they usually speedily melt into a liquid, in consequence of the great quantity of water which they contain. If the heat be continued the water is driven off, and the salt converted into a white powder. When the heat is urged farther, if the acid be of a combustible nature, it is destroyed; if it be volatile, it is driven off; but if it be fixed, the salt melts again at a red heat, and continues in a liquid state as long as the temperature is kept up. The salt, on cooling, is in the state of an opaque white mass, and is usually destitute of water.

3. No precipitate is produced in solution of salts of soda by tartaric acid, or nitromuriate of platinum; nor does sulphate of alumina added occasion the formation of octahedral crystals of alum: nor is any precipitate produced by infusion of nutgalls or ferro-chyazate of potash, except when the basis of the acid happens to be a metal.

4. One of the easiest methods of ascertaining whether the base of a given salt be soda,. is to determine the shape of the crystals which it forms. If it does not shoot into regular crystals, separate the acid by means of sulphuric or nitric acid, and let the new formed salt crystallize. Sulphate or nitrate of soda are easily recognized by the figure of their crystals.

1. Nitrate.

Sp. 1. *Nitrate of soda.* This salt was obtained at first by distilling a mixture of common salt and nitric acid in a retort, dissolving the residue in water, and evaporating. It was called *cubic nitre,* and is occasionally mentioned by the chemical writers of the early part of the last century; but it was Margraff who first analyzed it, pointed out the method of procuring it in a state of purity, and described its properties with accuracy.[*] His experiments were afterwards repeated by Dr. Lewis.[†]

It may be prepared by direct solution, or by mixing nitrate of lime and sulphate of soda together, filtering the solution, and evaporating. The crystals are transparent, and have a

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[*] Opusc. ii. 331.

[†] Phil. Com. p. 642.

rhomboidal form. This salt is of the specific gravity 2·0964.* It has a cool sharp taste, and is somewhat more bitter than nitre. It is soluble in about three parts of water at the temperature of 60°, in its own weight of water at the temperature of 126°,† and in less than its weight of boiling water. When exposed to the air it rather attacts moisture. Its phenomena in the fire are the same with those of nitre, excepting that it does not melt so easily.

The following table exhibits the result of the accurate experiments hitherto made to ascertain its constituents:

	‡	§	‖
Acid	62·1	62·5	62·81
Base	37·9	37·5	37·19
Total	100·0	100·0	100·0

Sp. 2. *Nitrite of soda.* Not hitherto examined.

3. Carbonate.

Sp. 3. *Carbonate of soda.* This salt has been also very long known. It is usually obtained by burning and lixiviating marine plants, or by decomposing common salt. In commerce it is called *barilla* or *soda.* In that state, however, it is never perfectly pure, containing always a mixture of earthy bodies, and usually common salt; but it may be purified by dissolving it in a small portion of water, filtrating the solution, and evaporating it at a low heat, skimming off the crystals of common salt as they form on its surface.** Of this salt there are three subspecies; namely, the *carbonate, sesquicarbonate,* and *bicarbonate.*

(1.) *Carbonate.* This is the common carbonate of soda of commerce. It forms large and beautiful crystals, the primitive form of which is supposed to be an octahedron composed of two four-sided pyramids with rhomboidal bases, applied base to base. But I am not aware that this form has ever been met with. At least I have never seen it myself, though I have examined several hundred fine crystals of this salt. The usual crystal is the preceding with the opposite acute angles of the rhomboidal base pretty deeply truncated, somewhat similar to the outline given in the margin.

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Wenzel, p. 309.

‡ Richter, Statique Chimique, i. 39.

§ Wenzel, Verwandtschaft, p. 81.

‖ Theoretical composition.

** See a detail of the different plants from which this substance is procured, and of the method of procuring them, in the Ann. de Chimie, vol. xlix. 267.

Its taste is precisely the same with that of the carbonate of potash. Its specific gravity is 1·623 by my trials. It is soluble in two parts of cold water, and in rather less than its weight of boiling water. So that when dissolved in boiling water it crystallizes as the solution cools. When exposed to the air, it very soon effloresces and falls to powder. When heated, it undergoes the watery fusion; indeed the soda of commerce sometimes contains so much water of crystallization, that, when once melted, it remains permanently liquid. If the heat be continued, the water gradually evaporates, and the salt becomes dry. In a red heat it melts into a transparent liquid. A very violent heat drives off a part of its acid. This salt melts rather more easily than carbonate of potash, and for that reason it is preferred by glass manufacturers.

Its constituents, according to the best analyses of it hitherto made, are as follows:

	*	†	‡	‡	§	‖
Acid	16	16	14·42	40·14	14·16	14·38
Base	20	22	21·58	59·86	20·60	20·92
Water	64	62	64·0		65·24	64·70
Total	100	100	100·00	100·00	100·00	100·00

The crystals are composed of 1 atom of the anhydrous salt + 11 atoms water.

(2) *Sesquicarbonate.* Though this salt occurs native in Africa in considerable quantities, it was not distinguished from the soda of commerce till, in 1802, Klaproth published an account of it in the third volume of his works.[**] It is found in the province of Sukena near Fezzan, and is called *trona* by the natives. It is crystallized in hard striated masses, not altered by exposure to the air, and of such hardness that the walls of Cassar, a fort now in ruins, are said to have been built of it. It may be formed artificially by exposing the common carbonate of soda to an atmosphere of carbonic acid gas. In that situation it does not deposit crystals like bicarbonate of potash, but forms a solid shapeless mass, having some resemblance to the African salt.

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[*] Bergman, Opusc. i. 18; and Fourcroy, Systeme de Connoisances, iv. 56. Engl. Trans.

[†] Klaproth, iii. 65. Engl. Trans.

[‡] Kirwan, Nicholson's Jour. iii. 215.

[§] By my analysis.

[‖] Theoretical composition.

[**] Beitrage, iii. 83.

An artificial sesquicarbonate of soda made by Mr. Philip Taylor, has been examined by Mr. Richard Phillips. It was crystallized in rhomboidal prisms, with angles of 60° and 120° terminated by quadrangular pyramids, the planes of the pyramids replacing the solid angles of the prism. It was not altered by exposure to the air, and the aqueous solution reddened turmeric paper strongly.* The following are the constituents of this salt according to the analysis of Klaproth and Phillips.

	†	‡
Acid	39	40·00
Base	38	39·72
Water	23	20·28
	100	100·00

If we suppose it a compound of 3 atoms acid + 2 atoms base + 4 atoms water, its constituents will be

Acid	8·25	or	39·76
Base	8·00		38·55
Water	4·50		21·69
			100·00

These numbers come sufficiently near the analyses to demonstrate its composition to be as above stated.

(3.) *Bicarbonate of soda* can only be formed by forcing carbonic acid into a solution of carbonate of soda by means of a strong pressure. The bicarbonate gradually falls down in the state of crystals. It is made chiefly in London, and employed in the manufacture of soda water.

4. Borate.

Sp. 4. *Borate of soda.* Of this salt there are two subspecies, namely, *borate of soda* and *borax*.

Subspecies 1. *Borate.* This salt, which may be formed by saturating borax with boracic acid, has never been examined. Bergman informs us, that about half its weight of boracic acid is necessary to saturate borax.§ Its specific gravity is 1·351.‖ It is soluble in 2·5 of water at the temperature of 147°.**

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* Quarterly Journal, vii. 296.

† Klaproth, Beitrage, iii. 83.

‡ Phillips, Quarterly Journal, vii. 296.

§ Bergman, iii. 325. According to Withering, twice its weight is necessary. Bergman's Sciagraphia, p. 26. Eng. Trans.

‖ Hassenfratz, Ann. de Chim. xxviii. 12.

** Wenzel, Ibid. p. 309.

From the experiments of Wenzel, the proportion of its constituents seems to be*

Acid	100
Base	44

But no confidence can be put in this analysis. Berzelius attempted to ascertain its composition, but met with difficulties which he was unable to surmount.

History.

Subspecies 2. *Borax.* This salt, the only one of the borates which has been accurately examined, is supposed to have been known to the ancients, and to be the substance denominated *chrysocolla* by Pliny. At any rate, it is mentioned by Geber as early as the ninth century under the name of *borax.* Its composition was first pointed out by Geoffroy in 1732, and by Baron in 1748. Bergman was the first who demonstrated that it has an excess of base, and is therefore in the state of a sub-borate.

This salt is brought from the East Indies in an impure state, under the name of *tinkal*, enveloped in a kind of fatty matter, which Vauquelin has ascertained to be a soap with soda for its base. When purified in Europe, it takes the name of *borax.* The purification was formerly performed by the Dutch, and of late by the British; but the process which they follow is not known. Valmont Bomare informs us that they extract 80 parts of pure borax from 100 parts of tinkal. The operations are conducted in leaden vessels, and consist chiefly in repeated solutions, filtrations, and crystallizations. Valmont Bomare suspects that they employ lime-water; and Fourcroy has shown that this might be useful in decomposing the soap in which crude borax is enveloped.†

Properties.

Borax, thus purified, may be obtained crystallized in hexangular prisms, of which two sides are much broader than the remainder, and terminated by triangular pyramids. It is of a white colour. Its specific gravity is 1·740.‡ It converts vegetable blues to green. Its taste is styptic and alkaline.

It is soluble, according to Wallerius, in 20 times its weight of water of the temperature of 60°, and six times its weight of boiling water.

When exposed to the air it effloresces slowly and slightly.

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* Verwandtschaft, p. 248.

† Fourcroy, iii. 330.

‡ Kirwan. Wallerius makes it 1·720 (Chemistry, p. 266); Dr. Watson 1·757 (Essays, v. 67.)

When heated, it swells, loses about four-tenths of its weight, becomes ropy, and then assumes the form of a light porous, and very friable mass, known by the name of *calcined borax;* in a strong heat it melts into a transparent glass still soluble in water.

When two pieces of borax are struck together in the dark, a flash of light is emitted.*

This salt, according to Bergman, is composed of

34	acid
17	soda
49	water
100†	

If these proportions were accurate they would indicate 3 atoms of acid united to 1 atom of soda. But no confidence can be placed in them. The analysis of Gmelin, however, agrees exactly with that of Bergman, in the proportion of acid and base. He found it a compound of

Acid	35·6
Soda	17·8
Water	46·6
	100·0‡

Sp. 5. *Silicate of soda.* This salt may be easily formed by fusing 2 parts by weight of soda with 1 part of silica. The mixture melts into a transparent glass, which attracts moisture when exposed to the air, is soluble in water, and is then known by the name of *liquor silicum.* Glass is a supersilicate of soda, usually containing a great excess of silica.

6. Phosphate.

Sp. 6. *Phosphate of soda.* This salt exists ready formed in urine, and was the first known of all the phosphates. It occupied a good deal of the attention of chemists; and the difficulty of analyzing it gave occasion to various hypotheses concerning its nature. Hellot remarked it in urine; and described it, in 1737, as a salt different from those that had usually been observed. Haupt described it in 1740 under the name of *sal mirabile perlatum*, or "wonderful perlated salt." It was called *perlated* from the grey, opaque, pearl-like colour which

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* Accum, Nicholson's Jour. ii. 28.

† Bergman's Notes on Scheffer, p. 106.

‡ Schweigger's Journal, xv. 245.

it assumed when melted by the blow-pipe. Margraff examined it in 1745, and found it would not yield phosphorus when treated with charcoal as the other salts of urine did, but ascertained that it contained phosphoric acid. Rouelle the Younger analysed it in 1776; and concluded from his experiments that it was a compound of phosphoric acid and soda;* but Mr. Proust, being unable to obtain phosphorus from it, concluded that its acid was not the phosphoric, but another analogous to the boracic.† To this substance, which Mr. Proust actually obtained, Bergman gave the name of *perlated acid*, and Morveau afterwards called it *ouretic acid*. But Mr. Klaproth soon after analyzed it, and proved that it consisted of soda supersaturated with phosphoric acid.‡ Scheele soon after made the same discovery.§ The acid of Mr. Proust, then, is merely phosphate of soda combined with phosphoric acid, or *biphosphate of soda*.

Dr. Pearson, who introduced it into medicine as a purgative, gave the following process for preparing it.

Preparation.

Dissolve in a long necked matrass 1400 grains of crystallized carbonate of soda in 2100 grains of water at the temperature of 150°. Add gradually 500 grains of phosphoric acid of the specific gravity 1·85. Boil the liquor for some minutes; and while it is boiling hot, filtrate it, and pour it into a shallow vessel. Let it remain in a cool place, and crystals will continue to form for several days. From the above quantities of materials he has obtained from 1450 to 1550 grains of crystals. Apothecaries usually prepare it from the superphosphate of lime, obtained from bones by means of sulphuric acid. An excess of carbonate of soda is added to separate the lime. The liquid is then filtered and evaporated slowly till it crystallizes.

Properties.

Its crystals are rhomboidal prisms, of which the acute angles are 60°, and the obtuse angles 120°, terminated by a three-sided pyramid. Its specific gravity is 1·333.‖ Its taste is cooling and urinous, but not disagreeable. It is soluble at the temperature of 60° in about four parts of water, and in two parts of boiling water. This solution crystallizes on cooling; but, in order to obtain the salt properly crystallized, the solution should contain a slight excess of alkali. When exposed to the air, this salt very soon effloresces on the surface. When

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* Jour. de Med. 1776, Juillet.

† Jour. de Phys. 1781, i. 145.

‡ Crell's Annals, 1785, i. 238.

§ Ibid. ii. 387.

‖ Hassenfratz, Ann. de Chim. xxviii. 12.

heated, it undergoes the watery fusion. At a red heat it melts into a white enamel. Before the blow-pipe it melts into a transparent globule, which becomes opaque on cooling, and its surface acquires a polyhedral figure.

It is not altered by combustibles nor metals. With metallic oxides it enters into fusion, and forms a coloured globule of glass. Sulphuric, nitric, and muriatic acids, decompose it partially, and convert it into *biphosphate of soda.* In this state it is more soluble in water, and not so easily crystallized; but may be obtained by proper evaporation in the state of thin scales, not unlike boracic acid. It was this biphosphate which Proust obtained, and which he considered as a peculiar acid. **Biphosphate.**

The greater number of earths may be fused along with this salt, and converted into glass.

This salt is composed as follows:

	*	*
Acid	20·33	100
Base	17·67	87
Water	62·00	
	100·00	

The crystals are composed of 1 atom anhydrous salt + 14 atoms of water. In my experiments on this salt, I found the water of crystallization rather more than 62 per cent. though probably it is less than 63.

Sp. 7. *Ammonio-phosphate of soda.* Though this salt, known to chemists by the names of *microcosmic salt* and *fusible salt of urine*, was extracted from urine, and examined much sooner than any of the other phosphates, it was long before philosophers were able to form precise notions concerning its nature, or even to obtain it in a state of purity. Margraff was the first who pointed out the method of procuring it pure, and who published a detailed description of its properties. He showed that it contained ammonia, and that it yielded phosphorus; but he did not succeed in discovering its whole constituents.[†] Fourcroy was the first who gave a precise account of the proportion of its component parts.[‡] According to him, it is composed of

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[*] Berzelius, Ann. de Chim. et Phys. ii. 164.

[†] Opusc. i. 123.

[‡] Ann. de Chim. vii. 183.

32 acid
24 soda
19 ammonia
25 water

100

The properties of this salt are nearly those of the phosphate of soda and phosphate of ammonia joined together. It answers better than the first of them as a flux; because the heat soon drives off the ammonia, and leaves an excess of acid. Its specific gravity is 1·509.* When exposed to the air, this salt effloresces, and gradually loses its ammonia; a fact first observed by the Duke de Chaulnes. Margraff had observed that the ammonia is dissipated when the solution of it in water is evaporated.

Sp. 8. *Phosphite of soda.* This salt has not been hitherto described.

Sp. 9. *Hypophosphite of soda.* This salt is very soluble in water and equally soluble in alcohol. A detailed account of its properties has not been hitherto published.†

10. Sulphate.

Sp. 10. *Sulphate of soda.* This salt was first discovered by Glauber, a German chemist, and for that reason was long known by the name of *Glauber's salt.* He himself called it *sal mirabile.* It may be prepared by saturating soda with sulphuric acid; but it is more usually obtained by decomposing common salt in order to procure muriatic acid. Like the sulphate of potash, it is capable of existing in two states. In the one it is neutral, in the other it has an excess of acid.

Properties.

Subspecies 1. *Sulphate.* This is the state in which the salt usually occurs in commerce, being prepared in great quantities by the manufacturers of sal ammoniac. Its crystals are transparent, and when formed by slow evaporation, are six-sided prisms, terminated by dihedral summits. The sides of the prisms are usually channelled, and the crystals are almost always exceedingly irregular. Its specific gravity, according to Wallerius, is 2·246;‡ Dr. Watson, by a method not susceptible of much precision (on account of the ready solubility of this salt), found it 1·380.§

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Ann. de Chim. et Phys. ii. 142.

‡ Wallerius' Chemia Physica, 266.

§ Chemical Essays, v. 66. I found the specific gravity of the salt 1·3497.

Its taste at first has some resemblance to that of common salt, but soon becomes very disagreeably bitter. It is soluble in 2·86 times its weight of water at the temperature of 60°, and in 0·8 of boiling water.[*] When heated to redness, so as to drive off its water of crystallization, and then pounded in a mortar, it dissolves in 3·3 its weight of water at the temperature of 144°.[†] When exposed to the air, it loses great part of its water, and falls into a white powder,[‡] but it is not otherwise altered. It loses about 56 *per cent.* of its weight.[§]

When exposed to heat, it first undergoes the *watery fusion*,[‖] then its water is evaporated, it is reduced to a white powder, and in a red heat it melts. Mr. Kirwan has observed, that part of the acid, as well as the water, is driven off by the application of a strong heat.[**]

Its constituents, according to the most accurate analyses hitherto made, are as follows:

	††	‡‡	§§	‖‖	***	†††
Acid	23·52	55·7	56	24·76	52·78	24·4
Base	18·48	44·3	44	19·24	47·22	19·6
Water	58·00			56·00		56·0
	100·00	100·0	100	100·00	100·00	100·0

The crystals of this salt are composed of 1 atom anhydrous sulphate + 10 atoms water.

Gay-Lussac has discovered that water of the temperature of 91° dissolves a maximum of anhydrous sulphate of soda. At that temperature, 100 parts of water dissolve 50·65 parts of the salt. The solubility diminishes a little as the temperature increases, and 100 parts of water at the boiling temperature dissolve only 42·65 parts of the salt. The solubility diminishes at a still greater rate, as the temperature sinks, so that

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[*] Bergman, i. 133.

[†] Wenzel, p. 309.

[‡] Substances which fall to powder in this manner are said to *effloresce*.

[§] Wenzel, p. 312.

[‖] When substances, on the application of heat, melt by means of the water they contain, they are said to undergo the watery fusion.

[**] Irish Transactions, v.

[††] Kirwan, Nicholson's Quarto Jour. iii. 215.

[‡‡] Wenzel's Verwandtschaft, p. 56.

[§§] Kirwan, Ibid. The two first analyses were made upon the crystals of the salt, the two last upon the salt supposed free from water.

[‖‖] Berzelius, Ann. de Chim. lxxxii. 33.

[***] Berard, Ann. de Chim. lxxi. 69.

[†††] Theoretical composition.

100 parts of water at the freezing point dissolve only 5·02 parts of the anhydrous salt. The following table exhibits the results of Gay Lussac's experiments on the solubility of this salt both anhydrous and crystallized. The temperatures are marked according to the centigrade scale.*

SALTS SOLUBLE IN 100 WATER.

Temperature.	Anhydrous.	Crystals.
0·00°	5·02	12·17
11·67	10·12	26·38
13·30	11·74	31·33
17·91	16·73	48·28
25·05	28·11	99·48
28·76	37·35	161·53
30·75	43·05	215·77
31·84	47·37	270·22
32·73	50·65	322·12
33·88	50·04	312·11
40·15	48·78	291·44
45·04	47·81	276·91
50·40	46·82	262·35
59·79	45·42	
70·61	44·35	
84 82	42·96	
103·17	42·65	

Subspecies 2. *Bisulphate.* When the sulphate of soda is dissolved in sulphuric acid, if the solution be set aside, it deposites spontaneously large rhomboidal crystals which contain an excess of acid. They effloresce in the air, and lose their excess of acid when moderately heated. At the temperature of 66° they dissolve in twice their weight of water.†

Sp. 11. *Ammonio-sulphate of soda.* This salt was first described by Link, who formed it by saturating supersulphate of soda with ammonia. Seguin formed it by mixing together the solutions of sulphate of soda and sulphate of ammonia, and evaporating the mixture. The triple salt is obtained in crystals. These crystals are regular, and are not altered by exposure to the air. Their taste is pungent and bitter. When heated they decrepitate and swell, ammonia is first disengaged, and supersulphate of ammonia and sulphate of soda remain. Soda decomposes it by driving off the ammonia.‡

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* Annals of Philosophy, xv. 10.

† Jour. de Min. An. 10. p. 80.

‡ Crell's Annals, 1796, i. 30.

According to Link it is composed of

5	parts sulphate of soda
9	parts sulphate of ammonia
14[*]	

Sp. 12. *Sulphite of soda.* This salt was first accurately described by Fourcroy and Vauquelin. It is white and perfectly transparent. Its crystals are four-sided prisms, with two very broad sides and two very narrow ones, terminated by dihedral summits. Its specific gravity is 2·9566.[†] Its taste is cool and sulphureous. It is soluble in four times its weight of cold water, and in less than its weight of boiling water. By exposure to the air it effloresces, and is slowly converted into a sulphate. When exposed to heat it undergoes the watery fusion, and afterwards exhibits precisely the same phenomena as the sulphite of potash. Metallic oxides and salts affect it precisely as they do sulphite of potash. The composition of this salt must be as follows:

Acid	24·5
Soda	24·5
Water	51·0
	100·0

The crystals are composed of 1 atom of anhydrous salt + 8 atoms water.

13. Hyposulphite.

Sp. 13. *Hyposulphite of soda.* This salt may be formed precisely in the same way as the hyposulphite of potash. It crystallizes on cooling, when evaporated to a syrup, in silky tufts, radiating from a centre, which at length extend through the whole liquid, and render it solid. When exposed to the air it deliquesces, but in vacuo along with sulphuric acid it effloresces. Its taste is intensely bitter and nauseous. When heated, it first undergoes the watery fusion, then dries into a white mass, and at length takes fire, burning with a vivid deflagration, and a bright yellow flame. It is insoluble in alcohol, which precipitates it from water Chloride of silver dissolves in it almost as readily as sugar in water.[‡]

Sp. 14. *Hyposulphate of soda.* Not yet described.

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[*] Link, Crell's Annals, 1796, i. 27.

[†] Hassenfratz, Ann. de Chim. xxviii. 12.

[‡] Herschell, Edin. Phil. Jour. i. 19.

15. Seleniate. Sp. 15. *Seleniate of soda.* Soda like most of the bases unites with three proportions of selenic acid, and forms three distinct salts.

(1.) *Seleniate* of soda is very soluble in water, and has the taste of borax. When evaporated to a syrup, it yields small crystalline grains; but cannot be made to crystallize by cooling. When evaporated to dryness, it does not alter in the air. It is insoluble in alcohol.

(2.) *Biseleniate* of soda crystallizes in needles when the solution is sufficiently concentrated. It does not effloresce in the air; but when heated, it first loses its water of crystallization, and then melts into a yellow liquid. On cooling, it becomes white. When heated to redness, one half of the acid flies off in a white smoke, and neutral seleniate remains.

(3.) *Quadriseleniate* of soda, when exposed to spontaneous evaporation, crystallizes in needles.

According to the analysis of Berzelius, seleniate of soda is composed of

Acid	100
Soda	55

While biseleniate is a compound of

Acid	100
Soda	28·48*

If we suppose an atom of selenic acid to weigh 7·125, and an atom of soda 4, then the true composition of these salts will be as follows:

	Seleniate.	Biseleniate.
Acid	100	100
Soda	56·14	28·07

16. Arseniate. Sp. 16. *Arseniate of soda.* This salt may be formed by dissolving carbonate of soda in arsenic acid, till all effervescence ceases; but care must be taken to leave the liquid in such a state that it shall still continue to redden vegetable blue colours. When sufficiently concentrated, and set aside, it yields very regular crystals of arseniate of soda.

The shape of its crystals is a rhomboidal prism, whose faces are inclined to each other at angles of 64° and 116°. The bases of these prisms are rhombs, with angles of 64° and 116°. In a dry atmosphere, they effloresce on the surface be-

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* Ann. de Chim. et de Phys. ix. 258.

coming white and opaque; but do not lose their shape, or fall to powder. The taste of the salt is cooling, and bears some resemblance to that of carbonate of soda, but is not so strong. These crystals give a *purple* colour to cudbear paper. Their specific gravity is 1·759; 100 parts of water at the temperature of 45° dissolve 22·268 parts of the crystals, or 10·132 parts of the salt deprived of its water of crystallization. Alcohol does not dissolve it; but a crystal suspended in that liquid becomes white and opaque, in consequence of the alcohol depriving the surface of the salt of its water of crystallization. When heated, it undergoes the watery fusion, the water of crystallization being more than sufficient to keep it in solution at a boiling temperature. When kept for some time in a temperature between 500° and 600°, it loses the whole of its water of crystallization, and is converted into a white powder. At a red heat it fuses, and becomes liquid like water.

The constituents of this salt, according to my analysis of it, are as follows:

Acid	34·00 or	14·5
Soda	9·38	4
Water	56·62	24·11

Now this is equivalent to 1 atom acid + 1 atom soda + 21 atoms water.*

Sp. 17. *Arsenite of soda.* A yellow viscid liquor with a nauseous odour. It does not crystallize.

Sp. 18. *Antimoniate of soda.* Not examined.

19. Chromate. Sp. 19. *Chromate of soda.* This salt has been examined by John.† When the acid is neutralized by soda, it forms a dark yellow solution, which by spontaneous evaporation forms thin six-sided tables, with two long and four short faces. They are transparent, easily soluble in water, and do not alter vegetable blues. They dissolve very sparingly in alcohol.

Sp. 20. *Molybdate of soda.* This salt is very soluble in water. The solution, by evaporation, yields transparent crystals not altered by exposure to the air.‡ Neither the molybdate of potash nor soda can be volatilized by heat.

21. Tungstate. Sp. 21. *Tungstate of soda.* This salt may be obtained by dissolving tungstic acid in a solution of soda. When the solution is evaporated, the tungstate of soda crystallizes in elongated hexahedral plates.

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* Annals of Philosophy, xv. 32.

† Ibid. iv. 425.

‡ Heyer, Gren's Handbuch, iii. 709.

It has an acrid and caustic taste; it is soluble in four parts of cold water, and in two parts of boiling water. Sulphuric, nitric, muriatic, acetic, and oxalic acids, occasion a precipitate in its solution, which is a triple salt, varying according to the acid employed. Phosphoric acid occasions no precipitate, nor is any precipitate produced when sulphuric acid is dropped in after phosphoric acid. No precipitate is occasioned by the sulphates of potash and of magnesia; but a white precipitate is occasioned by the following salts:

1. Muriates of lime and barytes; alum.
2. Almost all metallic salts.[*]

Sp. 22. *Columbate of soda.* Unknown.

23. Acetate.

Sp. 23. *Acetate of soda.* This salt, which seems to have been first examined by Baron, was formerly known by the absurd name of *crystallized foliated earth.* It is usually prepared by saturating acetic acid with carbonate of soda, and evaporating the solution till a thin pellicle appears on its surface. When the solution is allowed to cool, the acetate of soda crystallizes in striated prisms, not unlike those of sulphate of soda. It has a sharp taste, approaching to bitter. It is soluble in 2·86 parts of water at the temperature of 60°.[†] Its specific gravity is 2·1.[‡] It is not affected by exposure to the air. When heated, it first loses its water of crystallization; in a strong heat it melts; and in a still stronger its acid is destroyed. This salt can only be obtained in crystals when there is an excess of alkali in the solution.

The constituents of this salt, according to the best analyses hitherto made, are as follows:

Composition.

	§	‖	**	**	††
Acid....	60·39	.. 63·28	.. 61·689	.. 36·95	.. 61·45
Base....	39·61	.. 36·72	.. 38·311	.. 22·94	.. 38·55
Water ..				40·11	..
Total ..	100·00	100·00	100·000	100·00	100·00

Sp. 24. *Benzoate of soda.* The crystals of this salt are larger, but its taste is the same with that of benzoate of potash. It is also very soluble in water. It effloresces in the air.

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[*] Vauquelin and Hecht, Jour. de Min. No. 19, p. 20.

[†] Bergman, v. 78.

[‡] Hassenfratz, Ann. de Chim. xxviii. 12.

[§] Wenzel, p. 147.

[‖] Richter, Statique Chimique, i. 136.

[**] Berzelius, Ann. de Chim. lxxxii. 113.

[††] Theoretical composition.

25. Succinate.

Sp. 25. *Succinate of soda.* When pure succinic acid is saturated with soda, the solution by spontaneous evaporation yields beautiful transparent crystals of succinate of soda; some of which are four-sided prisms with dihedral summits; others six-sided prisms, terminated by an oblique face.* This salt has a bitter taste, is less soluble in water than common salt, and does not deliquesce when exposed to the air.

This salt is decomposed completely when exposed to a sufficient heat in close vessels.

Sp. 26. *Moroxylate of soda.* Unknown.

27. Camphorate.

Sp. 27. *Camphorate of soda.* This salt may be formed precisely in the same manner as the camphorate of potash. It is white and transparent; its taste is somewhat bitter; its crystals are irregular. Water at the temperature of 60° dissolves less than $\frac{1}{100}$ part of its weight of this salt; boiling water dissolves $\frac{1}{8}$th of its weight. It is also soluble in alcohol. When exposed to the air it loses its transparency, and effloresces slightly, but is never completely reduced to powder. Heat produces the same effect upon it as on camphorate of potash: the acid burns with a blue flame, which becomes reddish towards the end.†

Sp. 28. *Suberate of soda.* This salt does not crystallize. It reddens the tincture of turnsole. Its taste is slightly bitter. It is very soluble in water and in alcohol. It attracts moisture from the air. Caloric produces the same effect on it that it does on suberate of potash.‡

29. Oxalate.

Sp. 29. *Oxalate of soda.* When two parts of crystallized carbonate of soda are dissolved in one part of oxalic acid, the oxalate of soda partly precipitates, because it is but sparingly soluble in water. The remaining solution yields by evaporation crystalline grains, which give a green tinge to syrup of violets, and are perfectly soluble in hot water.§ The taste of this salt is nearly the same as that of oxalate of potash, but it is much less soluble in water. When heated it falls to powder, and loses the whole of its water of crystallization.

The constituents of this salt are

Oxalic acid	53
Soda	47
	100

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* Morveau, Ann. de Chim. xxix. 166.

† Ann. de Chim. xxvii. 26.

‡ Ann. de Chim. xxiii. 52.

§ Bergman, i. 261.

In my original experiments,[*] I made the quantity of oxalic acid too great, because my acid was not sufficiently freed from water. M. Berard fell into the same mistake.[†] The analysis of Vogel of Bayreuth is nearly correct; he obtained

Acid	54·77
Soda	45·23
	100·00[‡]

Sp. 30. *Mellate of soda.* When mellitic acid is neutralized by soda, the solution crystallizes in cubes or three-sided tables; sometimes insulated, sometimes in groups.[§]

31. Tartrate.

Sp. 31. *Tartrate of soda.* This salt may be formed by dissolving soda in tartaric acid. It crystallizes in fine needles. Its specific gravity is 1·7437.[||] It is soluble in its own weight of cold water.[**] It is capable of combining with an excess of acid, and forming a *supertartrate* of soda, which is nearly as insoluble in water as tartar.[††]

Sp. 32. *Tartrate of potash-and-soda.* This salt is usually prepared by putting one part of tartar in five parts of boiling water, and adding gradually carbonate of soda in powder as long as it continues to produce an effervescence. The tartar gradually dissolves. When the saturation is complete, the solution is filtered and evaporated to the consistence of a syrup. On cooling, the tartrate of potash-and-soda crystallizes.

History.

This salt has been distinguished by the name of *salt of seignette,* because it was first formed and introduced into medicine by Mr. Seignette, an apothecary at Rochelle. This gentleman recommended it in a tract published in 1672. It was soon after introduced into practice in Paris by Lemery; and, becoming a fashionable medicine, made the fortune of the discoverer. For some time its composition was kept secret; but Boulduc and Geoffroy discovered its component parts in 1731.

This salt crystallizes in prisms of eight or ten unequal sides, having their ends truncated at right angles. They are generally divided into two in the direction of their axes; and the base on which they stand is marked with two diagonal lines, so as to divide it into four triangles. It has a bitter taste. It

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[*] Phil. Trans. 1808.

[†] Ann. de Chim. lxxiii. 274.

[‡] Annals of Philosophy, v. 30.

[§] Klaproth's Beitrage, iii. 131.

[||] Hassenfratz, Ann. de Chim. xxviii. 12.

[**] Wenzel, p. 308.

[††] Thenard, Ann. de Chim. xxviii. 12.

is almost as soluble as tartrate of potash. It effloresces when exposed to the air. Heat decomposes it. Its specific gravity is 1·757.*

According to the analysis of Vauquelin, it is composed of

54 tartrate of potash
46 tartrate of soda
100†

If we consider it as composed of an atom of tartrate of potash united to 1 atom of tartrate of soda, which is obviously its composition, it must consist of

Tartrate of potash	53·73
Tartrate of soda	46·27
	100·00

Now these proportions agree very closely with the result of Vauquelin's analysis.

Sp. 33. *Citrate of soda.* This salt may be formed by the same process as the 31st species. By proper evaporation it is obtained crystallized in six-sided prisms, not terminated by pyramids. Its taste is salt and cooling, but mild. It is soluble in 1$\frac{2}{3}$ parts of water. When exposed to the air, it effloresces slightly. When heated, it melts, swells, bubbles up, blackens, and is decomposed. According to Vauquelin, it is composed of

60·7 acid
39·3 soda
100·0‡

If we consider it as composed of 1 atom acid + 1 atom soda, its constituents must be

Citric acid	7·375	64·83
Soda	4·000	35·17
		100·00

Sp. 34. *Kinate of soda.* Unknown.

Sp. 35. *Saclactate of soda.* Small crystals soluble in 5 times their weight of boiling water.§

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* Watson's Chemical Essays, v. 67.

† Fourcroy, vii. 246.

‡ Ibid. vii. 247.

§ Scheele on sugar of milk.

Sp. 36. *Urate of soda.* A white powder having the same appearance as pure uric acid. Soluble in soda ley.

Sp. 37. *Malate of soda.* A deliquescent, very soluble, incrystallizable salt. The bimalate forms permanent crystals soluble in water; but insoluble in alcohol.*

Sp. 38. *Lactate of soda.* This salt bears a close resemblance to lactate of potash, from which it can only be distinguished by analysis.† It dissolves in alcohol.

The composition of the salts of soda is easily ascertained by considering them as composed of 1 atom of soda united to 1 atom of each of the acids. An atom of soda weighs four, and the weight of an atom of each of the acids has been given in a preceding chapter of this volume.

Perhaps the carbonate is the most useful of all the salts of soda. The sulphate is much employed as a cathartic. Rochelle salt likewise is much employed in medicine. But the great body of the salts of soda have not yet been applied to any useful purpose.

SECT. IV.

SALTS OF LITHIA.

The salts of lithia have been hitherto but superficially examined, owing to the difficulty of procuring their base in sufficient quantity.

General properties.

1. They are all soluble in water (as far as is known), and in this respect resemble the salts of potash and soda. But the carbonate of lithia is much less soluble than the carbonates of potash or soda.

2. When carbonate of potash is dropt into a concentrated solution of a salt of lithia, a white precipitate falls. This precipitate may be redissolved again by diluting the liquid with a sufficient quantity of water.

3. Muriate of platinum occasions no precipitate when dropt into a salt of lithia.

4. Several of the salts of lithia melt at a very low temperature.

5. When the salts of lithia are heated to redness in a pla-

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* Donovan.

† Berzelius, Djurkemien, ii. 436.

tinum vessel, they act with considerable energy upon that metal.

6. Neither ferrochyazate of potash, nor infusion of nut-galls, occasions any precipitate in the salts of lithia.

1. Nitrate.

Sp. 1. *Nitrate of lithia.* This salt is colourless, very soluble in water, and crystallizes in four-sided prisms, with rhomboidal bases. Its taste is very sharp. It very speedily deliquesces when exposed to the air. It melts when exposed to a very moderate degree of heat, and runs into a liquid. It dissolves readily in alcohol.*

2. Carbonate.

Sp. 2. *Carbonate of lithia.* When this salt is obtained by precipitating a concentrated salt of lithia by means of carbonate of potash, it is a white powder, having a strong alkaline taste, and soluble in about 100 times its weight of cold water; but more soluble in hot water. It melts when heated to redness, and assumes on cooling the appearance of enamel. When heated in a platinum crucible, the metal is always strongly attacked. The carbonates of the other alkalies, on the other hand, restore the metallic lustre to this metal when tarnished. This fused carbonate dissolves in water very slowly. According to the analysis of Gmelin, this carbonate is composed of

Carbonic acid . .	54·46	2·75
Lithia	45·54	1·932
	100·00	

The true numbers are doubtless

Carbonic acid	55	2·75
Lithia	45	2·25
	100	

which approach very nearly to the actual analysis.†

Sp. 3. *Borate of lithia.* This acid combines in two proportions with lithia. The neutral borate may be made by boiling together the aqueous solutions of boracic acid, and carbonate of lithia. The combination takes place very slowly. The borate of lithia is very soluble in water, and when the so-

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* Arvedson, Ann. de Chim. et de Phys. x. Gmelin, Gilbert's Annalen, lxii. 410.

† Gilbert's Annalen, lxii. 416. Arvedson, Ann. de Chim. et de Phys. x. 82.

lution is evaporated sufficiently, a gummy transparent matter remains, which deliquesces when left exposed to the air.

Biborate of lithia is capable of crystallizing, and is much less soluble than the borate of lithia, though more so than boracic acid.*

4. Phosphate.

Sp. 4. *Phosphate of lithia.* This salt falls in the state of a white insoluble powder, when phosphate of ammonia is dropt into a solution of sulphate of lithia. But phosphoric acid does not occasion a precipitate when dropt into that salt, nor when dropt into carbonate of lithia, But if heat be applied to the carbonate after the addition of phosphoric acid, carbonic acid is disengaged, and phosphate of lithia falls down. When we dissolve this salt in phosphoric acid, we obtain a biphosphate of lithia, which is capable of crystallizing.†

5. Sulphate.

Sp. 5. *Sulphate of lithia.* This salt crystallizes in small four-sided crystals, whose bases, according to Vauquelin, are squares. Its taste is saline, without any of the bitterness which distinguishes the sulphates of potash and soda. It requires a strong red heat to fuse it, but the presence of a little gypsum makes it fusible below a red heat. It is scarcely altered by exposure to the air. The constituents of this salt, according to the different analyses hitherto made, are as follows:

	‡	§	||	**
Acid	68·41	69·2	68·15	68·966
Lithia	31·59	30·8	31·85	31·034
	100·00	100·0	100·00	100·000

Bisulphate of lithia dissolves in water more readily than the sulphate. It crystallizes in six-sided tables. When exposed to a very high temperature, sulphurous acid and oxygen gas are driven off, and sulphate of lithia remains behind.††

Sp. 6. *Chromate of lithia.* This salt has a yellow colour, and crystallizes in parallelopipeds with rhomboidal bases. It is readily soluble in water.‡‡

Sp. 7. *Tungstate of lithia.* This salt may be obtained by

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* Gmelin, Gilbert's Annalen, lxii. 412.

† Ibid. p. 409.

‡ Arvedson, Ann. de Chim. et de Phys. x. 90.

§ Vauquelin, ibid. vii. 287.

|| Gmelin, Gilbert's Annalen, lix. 240.

** Theoretical composition.

†† Gmelin, Gilbert's Annalen, lxii. 409.

‡‡ Ibid. p. 413.

boiling together tungstic acid and carbonate of lithia with a sufficient quantity of water. It crystallizes in large oblique four-sided prisms, with rhomboidal bases. Its taste is sharp, and at first sweetish, but it leaves an astringent impression in the mouth. It is pretty soluble in water.*

Sp. 8. *Acetate of lithia.* This salt may be obtained by dissolving carbonate of lithia in acetic acid, with the assistance of heat. When evaporated, it leaves a gummy matter which speedily deliquesces, and in the deliquesced mass, crystalline plates gradually make their appearance.†

Sp. 9. *Benzoate of lithia.* Benzoic acid readily decomposes carbonate of lithia, and forms a salt which dissolves readily in water, and does not crystallize, but leaves a white opaque matter which deliquesces in the air. When heated to redness, it is converted into carbonate of lithia, which leaves when dissolved in water, a very bulky coal.‡

Sp. 10. *Oxalate of lithia.* This salt may be obtained by saturating oxalic acid with carbonate of lithia. It crystallizes with difficulty, and dissolves readily in water.§ Binoxalate of lithia crystallizes and dissolves readily in water.

Sp. 11. *Tartrate of lithia.* This salt dissolves readily in water, and does not crystallize, but forms a white opaque matter which does not deliquesce when exposed to the air. The *bitartrate*, on the contrary, crystallizes readily, and is not so soluble as the tartrate.‖

Sp. 12. *Tartrate of potash-and-lithia.* When the excess of acid in the bitartrate of potash is neutralized by boiling the salt with carbonate of lithia, and the liquid is left to spontaneous evaporation, we obtain large crystals, consisting of rectangular four-sided prisms, whose bases are rectangles. The diagonals of these rectangles are distinctly marked, and the four triangles thus produced are streaked parallel to the sides of the rectangle. This remarkable appearance is permanent, and may therefore constitute a good character of lithia. This salt dissolves readily in water. It has a salt taste, without any bitterness, and is scarcely altered by exposure to the air.**

Sp. 13. *Tartrate of soda-and-lithia.* This salt may be made by a process similar to that given for obtaining the preceding species. It forms long four-sided rectangular prisms, often terminated by an oblique face. It dissolves readily in water.

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* Gmelin, Gilbert's Annalen, lix. p. 413.

† Ibid. 415.

‡ Ibid. 416.

§ Ibid. 414.

‖ Ibid.

** Ibid. 417.

Its taste is saline and weak, and it undergoes little alteration when left exposed to the air.*

Sp. 14. *Saclactate of lithia.* Saclactic acid readily dissolves carbonate of lithia, and yields when slowly evaporated small crystals of saclactate of lithia, which effloresce when exposed to the air, and dissolve with facility in water.†

Sp. 15. *Malate of lithia.* Malic acid extracted from the berries of the mountain ash dissolves carbonate of lithia with facility; but the solution does not yield crystals. When evaporated, a syrupy mass remains which cannot be easily dried.‡

Sp. 16. *Gallate of lithia.* Gallic acid readily dissolves carbonate of lithia. The solution has a dark green colour, and when evaporated, leaves a black matter behind, which does not yield crystals.§

Such are the salts of lithia hitherto examined by chemists. Their composition is easily determined by considering them as compounds of one atom acid, and one atom lithia, and by recollecting that an atom of lithia weighs 2·25.

SECT. V.

SALTS OF MORPHIA.

THIS genus of salts has been known for so short a time, and has been so imperfectly examined, that we are not yet acquainted with the characters by which it may be distinguished from the three following genera.

General properties.

1. All the salts of morphia, as far as known, are soluble in water, and have a bitter taste. Most of them are capable of crystallizing.

2. When ammonia is dropt into a solution of a salt of morphia, a white flocky precipitate falls, which in a short time assumes a crystallized appearance. This precipitate reddens turmeric paper, has a bitter taste, and when taken internally, produces the same effects as a dose of opium.

Sp. 1. *Nitrate of morphia.* This salt crystallizes in needles, which are deposited in stars. Its taste is bitter, and it dissolves in 1½ time its weight of cold water. According to the analysis of Choulant, the composition of this salt is as follows:

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* Gmelin, Gilbert's Annalen, lix. p. 414.

† Ibid. 416. ‡ Ibid. § Ibid. 415.

Nitric acid	20
Morphia	36
Water	44
	100

But these proportions are probably very wide of the truth.*

Sp. 2. *Carbonate of morphia.* This salt crystallizes in short prisms, and is soluble in four times its weight of water. According to Sertürner, morphia is likewise capable of combining with carbonic acid, in the proportion of 2 atoms morphia to 1 atom carbonic acid, forming a sub-bicarbonate. It is more soluble in water than morphia. According to Choulant, the carbonate of morphia is composed of

Acid	28
Morphia	22
Water	50
	100†

But these numbers are without doubt very inaccurate.

Sp. 3. *Sulphate of morphia.* This salt crystallizes in prisms, and is soluble in twice its weight of distilled water. The following table exhibits the composition of this salt according to the analyses of it hitherto made.

	‡	§	||	**
Acid	22	12·8	11·084	11·05
Morphia	40	87·2	88·916	88·95
Water	38			
	100	100·	100·	100·

Sp. 4. *Acetate of morphia.* This salt crystallizes in white prisms. It has a bitter taste, and is soluble in its own weight of cold water.

Sp. 5. *Tartrate of morphia.* This salt crystallizes in prisms, and is soluble in thrice its weight of cold water.

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* Annals of Philosophy, xiii. 154.

† Ibid. p. 155.

‡ Choulant, ibid. p. 154.

§ Robiquet, Ann. de Chim. et de Phys. v. 280.

|| Pelletier and Caventou, Jour. de Pharm. v. 536.

** Theoretical composition.

SECT. VI.

SALTS OF STRYCHNIA.

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THIS genus of salts is not better known than the preceding genus. Hitherto indeed they have been partially examined by Pelletier and Caventou, only, the discoverers of strychnia.

1. They are all soluble in water, have an intensely bitter taste, and when taken internally, prove fatal by inducing tetanos.

2. When nitric acid is poured upon a salt of strychnia, and heat applied, the salt assumes a beautiful red colour.

Sp. 1. *Nitrate of strychnia.* To prepare this salt, we must dilute the acid with a great deal of water, and heat it with a quantity of strychnia, more than sufficient to saturate it. When this liquid is evaporated, it yields crystals of nitrate of strychnia, in pearl coloured needles, grouped together in the form of stars. Its taste is excessively bitter, and it acts with more violence upon the animal economy, than pure strychnia. It dissolves in much greater proportion in hot than in cold water. When heated, it becomes yellow, and when the heat is increased, it burns with considerable brilliancy. When strong sulphuric or muriatic acid is poured upon this salt, it assumes immediately a red colour.*

Sp. 2. *Carbonate of strychnia.* This salt may be obtained by mixing an alkaline carbonate with a salt of strychnia. It precipitates in white flocks. It seems to be a sub-bicarbonate. It is but little soluble in water, but dissolves readily in carbonic acid gas.†

Sp. 3. *Phosphate of strychnia.* This salt crystallizes in four-sided prisms. When we attempt to prepare it by dissolving strychnia in phosphoric acid, the liquid still retains its property of reddening vegetable blues. But this does not prevent the phosphate from separating in crystals.‡

Sp. 4. *Sulphate of strychnia.* This salt, when perfectly neutral, crystallizes in cubes. A small excess of acid gives it the form of needles. Its taste is excessively bitter. It dissolves in ten times its weight of cold water, and is still more soluble in hot water. It is scarcely altered by exposure to the air. When exposed to the temperature of 212° it becomes slightly opaque; but loses no weight. At a higher temperature it

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* Jour. de Pharm. v. 156.

† Ibid. 161.

‡ Ibid. 156.

fuses, and then becomes a dry matter. By this process, it loses three per cent. which may be considered the water of crystallization. At a still higher temperature it is decomposed and charred. Its constituents, according to the analysis of Pelletier and Caventou, are as follows:

Acid	9·5
Strychnia	90·5
	100·0[*]

Remaining salts. The acetic, oxalic and tartaric acids form with strychnia neutral salts very soluble in water, and more or less capable of assuming regular crystalline forms. It is obvious from this that the salts of strychnia are not precipitated by the acetates, oxalates, or tartrates.[†]

SECT. VII.

SALTS OF BRUCIA.

The characters of this genus of salts are very similar to those of the salts of strychnia. They do not act with the same violence on the animal economy, though their action is of the same nature. Nitric acid, when heated on them, give them a red colour, but the shade differs from that which the salts of strychnia assume when treated in the same way.

Sp. 1. *Nitrate of brucia.* This salt when neutral does not crystallize, but assumes when evaporated the appearance of gum. But the binitrate crystallizes very readily in four-sided prisms, terminated by bihedral summits. When heated, it becomes red, then blackens, and burns like nitrate of strychnia.[‡]

Sp. 2. *Phosphate of brucia.* This salt does not crystallize, unless there be an excess of acid present. It then crystallizes very readily in the form of rectangular tables, with bevelled edges. It is very soluble in water. When exposed to the air, it effloresces slightly. It dissolves in very small quantity in alcohol.[§]

Sp. 3. *Sulphate of brucia.* This salt crystallizes in long slender needles, seemingly four-sided prisms, terminated by pyramids. Its taste is intensely bitter. It is very soluble in

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[*] Jour. de Pharm. v. p. 154.

[†] Ibid. 161.

[‡] Pelletier and Caventou, Jour. de Pharm. v. 542.

[§] Ibid. 541.

water, and sparingly soluble in alcohol. The brucia is thrown down from it by all the alkalies and alkaline earths, and likewise by morphia and strychnia. But no acid tried is capable of decomposing it, except the concentrated nitric acid. But in this case the brucia is altered in its nature, and the usual red colour developed. The constituents of this salt, according to Pelletier and Caventou, are as follows:

Acid	8·84
Brucia	91·16
	100·00 *

Other species. *Acetate of brucia* is very soluble in water, and does not appear capable of crystallization. *Oxalate of brucia* crystallizes in long needles, at least when it contains an excess of acid.†

SECT. VIII.

SALTS OF PICROTOXIA.

THIS genus of salts is still too imperfectly known to admit us to give characters by which it may be distinguished from the other recently discovered genera with which it is so nearly allied.

General properties.

1. The salts of picrotoxia are all soluble in water, and the solution has often a yellow colour.

2. The taste of all these salts is bitter.

3. When an alkali or alkaline carbonate is dropt into them a white precipitate falls, which is the picrotoxia.

1. *Nitrate of picrotoxia.* Nitric acid of the specific gravity 1·38, diluted with twice its weight of water, dissolves (when assisted by heat) the fourth part of its weight of picrotoxia. When this solution is evaporated to one half, it becomes viscid and concretes on cooling into a transparent mass, similar to a solution of gum arabic. In this state the nitrate of picrotoxia has an acid and very bitter taste. If it be still farther dried in a temperature not exceeding 140°, it swells up, becomes opaque, and at last perfectly white, similar in appearance to calcined alum. If we keep it in this state at a temperature below that of boiling water, adding a little water occasionally, the whole excess of acid exhales, and the taste becomes purely

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[*] Pelletier and Caventou, Jour. de Pharm. p. 535. † Ibid. p. 543.

bitter. When this salt is washed in pure water, the acid is totally removed, and the picrotoxia separated in the state of fine white plates.

2. *Carbonate of picrotoxia.* When carbonic acid gas is passed through water in which picrotoxia is suspended, a portion of the acid is absorbed by the alkali; for it afterwards dissolves in acids with effervescence. But no solution takes place.

3. *Phosphate of picrotoxia.* Phosphoric acid diluted with twice its weight of water dissolves but little picrotoxia while cold. When assisted by heat it acts with some energy, and the phosphate crystallizes on cooling like the sulphate, but the size of the crystals is smaller. Phosphate of picrotoxia, even after being well washed, gives a red colour to vegetable blues. It dissolves in 50 times its weight of boiling water, and the solution becomes almost solid on cooling. The crystals are needles, retaining an excess of acid, and having an insupportably bitter taste.

4. *Sulphate of picrotoxia* must be formed by dissolving picrotoxia in dilute sulphuric acid; for the strong acid chars and destroys it. The solution crystallizes on cooling. The sulphate of picrotoxia dissolves in 120 times its weight of boiling water. From this solution the salt gradually falls in fine silky needles possessed of great beauty. When dry it has a white colour, and feels elastic under the teeth, like plumose alum. It is composed of

Sulpuric acid	9·99	5
Picrotoxia	90·01	45
	100·00	

5. *Acetate of picrotoxia.* Acetic acid dissolves picrotoxia very well, and may be nearly saturated with it when assisted by a boiling heat. On cooling, the acetate precipitates in well defined prismatic needles. This acetate is soluble in 50 times its weight of boiling water. When the solution cools, the salt is deposited in crystals possessed of great beauty, light without any acid smell, and much less bitter than picrotoxia itself. It is decomposed by nitric acid, which disengages the acetic acid. Dilute sulphuric acid has no marked action on it.

6. *Oxalate of picrotoxia.* Oxalic acid next to acetic acid has the property of saturating picrotoxia most completely. The salt crystallizes in triangular plates, having a moderately

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bitter taste. It dissolves in ten times its weight of boiling water, and is therefore the most soluble of all the salts of picrotoxia hitherto examined.

7. *Tartrate of picrotoxia.* Cold tartaric acid scarcely acts upon picrotoxia; but it dissolves that alkali when assisted by heat; and on cooling, the salt gradually separates in triangular needles. This salt has a very bitter taste. It is soluble in 20 times its weight of boiling, and in 160 times its weight of cold water. Its aqueous solution, though much diluted, is precipitated by lime water.*

SECT. IX.

SALTS OF DELPHIA.

This genus of salts is still more incompletely known than the preceding. The salts belonging to it have a bitter taste, and do not seem much disposed to form crystals.

1. *Nitrate of delphia.* This salt when made by dissolving delphia in very weak nitric acid is colourless. But when concentrated it assumes a yellow colour. When this nitrate is treated with an excess of acid, it is changed into a yellow matter, but little soluble in water. Boiling alcohol dissolves it with difficulty, and when potash, ammonia, or lime water, is added to this solution, no precipitate is formed. The taste of this new body is bitter. It does not appear to contain any nitric acid, and yet it possesses no alkaline properties. It is not altered by new doses of nitric acid, and cannot be converted into oxalic acid.

2. *Sulphate of delphia.* This salt does not crystallize; but when exposed to spontaneous evaporation dries into a transparent mass similar to gum. It dissolves readily in water and alcohol, and the solution has a bitter and acrid taste, which remains in the mouth for several hours. When a concentrated solution of this salt is acted on by a galvanic battery, the salt is decomposed, the sulphuric acid being deposited at the positive pole, and the delphia at the negative pole in white flocks.

3. *Acetate of delphia* when neutral does not crystallize; but dries into a hard transparent mass, having a very bitter and

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* Boullay, Jour. de Pharmacie, v. 10.

acrid taste. It is easily decomposed (like all the other acetates) by strong sulphuric acid.

4. *Oxalate of delphia* has the form of white plates, and has the same taste as the other salts of delphia.*

SECT. X.

SALTS OF LIME.

1. A CONSIDERABLE number of the salts of lime are insoluble in water. Some of those which are soluble cannot easily be crystallized.

General properties

2. When a salt of lime is insoluble in water, if we boil it for some time in a solution of carbonate of potash, a white powder remains, which is soluble with effervescence in nitric acid, and which possesses all the characters of carbonate of lime.

3. The soluble salts of lime are not altered by the addition of pure ammonia, but the addition of potash or soda occasions a white precipitate to fall, which is pure lime.

4. When oxalate of ammonia is dropped into a salt of lime, a dense white precipitate immediately begins to make its appearance; but citrate or tartrate of ammonia does not occasion an immediate precipitation.

5. The salts of lime are not precipitated by ferrochyazate of potash; but some of them are precipitated when the infusion of nutgalls is mixed with them.

1. Nitrate.

Sp. 1. *Nitrate of lime.* This salt has been long known to chemists. Native nitre is almost always contaminated with it. It may be prepared by dissolving carbonate of lime in nitric acid; evaporating the solution to the consistence of a syrup, and then allowing it to cool slowly. The salt is precipitated in the state of crystals.

Properties.

Its crystals are six-sided prisms, terminated by long pyramids; but it is oftener obtained in the form of long slender brilliant needles. Its taste is very acrid and bitter. Its specific gravity is 1·6207.† Scarcely any salt is more soluble in water. At the temperature of 60°, one part of water dissolves four parts of nitrate of lime, and boiling water dissolves any quantity of it whatever. Boiling alcohol dissolves its own

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* Lassaigne and Feneulle: Ann. de Chim. et de Phys. xii. 358.

† Hassenfratz, Ann. de Chim. xxviii. 12.

weight of it.[*] Considerable difficulty attends its crystallization, as is the case with all very soluble salts. When exposed to the air, it very soon attracts moisture, and melts altogether. This strong affinity for moisture renders it sometimes useful for drying the gases. They are made to pass through tubes containing dried nitrate of lime; and this salt, during their passage through it, abstracts great part of the water which they hold in solution.

This nitrate, when heated, readily undergoes the watery fusion. When the water of crystallization is evaporated, the salt becomes dry, and often acquires the property of shining in the dark. In that state it was formerly known by the name of *Balduin's phosphorus;* because this property of nitrate of lime was first pointed out by Balduin.[†] When strongly heated it is decomposed; nitrous gas, oxygen gas, and azotic gas are emitted, and the pure lime remains behind. This salt scarcely possesses the property of detonating with combustible bodies, in consequence probably of the great proportion of its water of crystallization.

The following table exhibits the result of the experiments made to ascertain the constituents of this salt:

Composition.

	[‡]	[§]	[‖]	[**]	[††]
Acid	43	57·44	63·9	66·2	65·06
Base	32	32·00	36·1	33·8	34·94
Water	25	10·56			
Total	100	100	100	100	100

2. Carbonate.

Sp. 2. *Carbonate of lime.* This substance, under the names of marble, chalk, limestone, &c. exists in great abundance in nature, variously mixed with other bodies. It is perhaps the most important and most generally used of all the salts, unless we except muriate of soda. Its properties of course have been very completely investigated.

Properties.

It is often found crystallized and perfectly transparent. The primitive form of its crystals is the rhomboidal prism with

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[*] Bergman, i. 136.

[†] His account of it was published in 1675, under the title of Phosphorus Hermeticus, seu Magnes Luminaris. See also Phil. Trans. Ab. ii. 368.

[‡] Bergman, i. 136.

[§] Kirwan, Nicholson's Jour. ii. 315.

[‖] Richter, Statique Chimique, i. p. 136.

[**] Wenzel, p. 81.

[††] Theoretical composition.

angles of 101½° and 78½°. Its integrant particles have the same form. But, besides the primitive, no less than 616 varieties of its crystals have been discovered and described by mineralogists. It has scarcely any taste. Its specific gravity is about 2·7. It is insoluble in pure water; but water saturated with carbonic acid dissolves $\frac{1}{1500}$th part of it; from this solution it gradually precipitates, as the acid leaves it, in the form of a white powder.* It suffers little or no alteration by being exposed to the air. When exposed to heat, it decrepitates and loses its water, and afterwards its acid separates as the heat is increased: but to separate the acid completely, a pretty strong heat is required.

Its component parts are as follows:

	†	‡	§	||	**
Acid	34	45	43·9	43·2	43·14
Base	55	55	56·1	56·8	56·86
Water	11				
Total	100	100	100	100	100

Fusibility.

Some very interesting experiments on the fusibility of this salt were made by Sir James Hall. The result was, that when the carbonic acid is prevented from making its escape by strong compression, the salt melts at a red heat, and assumes an appearance which has some resemblance to *granular limestone*. A portion of the carbonic acid is usually dissipated. This portion is sometimes very small, and very often it does not exceed 4 or 5 per cent. Bucholz has verified these experiments in a very unexpected manner. He put 4½ pounds of washed chalk (carbonate of lime with only 0·005 of foreign matter) into a crucible, pressed it strongly down, and exposed it covered to a strong heat in a furnace. The chalk, except a small portion on the surface, was converted into a foliated, hard, yellowish mass, having considerable transparency, which evidently had undergone a commencement of fusion. It was obviously in a similar state with Sir James Hall's carbonate of lime, and contained 42 per cent. of carbonic acid.†† Here the same effect was produced without compression. It must

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* Bergman, i. 26.

† Bergman, Opusc. i. 23.

‡ Kirwan, Nicholson's Journal, iii. 215.

§ Dr. Marcet, Nicholson's Journal, xx. 29.

|| By my analysis.

** Theoretical composition.

†† Gehlen's Jour. 2d Series, i. 271.

have depended, no doubt, upon the degree of heat to which the crucible was exposed.

Sp. 3. *Borate of lime.* This salt may be formed by mixing together lime-water and the aqueous solution of boracic acid, or by boiling together lime and pure borax in water. In either case, the borate of lime precipitates in the state of a white powder, tasteless, and difficultly soluble in water.*

4. Silicate.

Sp. 4. *Silicate of lime.* The mineral called *shalstein* or *table spar,* which has hitherto been observed only in the Bannat of Temeswar and in Ceylon is a *bisilicate of lime.* It has a greyish white colour, a pearly lustre, a foliated fracture, is semitransparent and semihard, and is composed, according to the analysis of Klaproth, of

Silica	50
Lime	45
Water	5

If we suppose it a compound of 2 atoms silica and 1 atom lime, its constituents would be

Silica	49·83
Lime	45·17
Water	5
	100·00

Now this almost coincides with the analysis.

The water, which amounts only to 0·4 of an atom, is probably only mechanically mixed with the salt.

5. Borosilicate.

Sp. 5. *Borosilicate of lime.* The mineral called *datholite,* discovered by Esmark, near Arendal in Norway, is a borosilicate of lime. It has a greyish or greenish white colour, and is found crystallized in flat rectangular four-sided prisms, having their angles truncated. It is semitransparent, pretty hard, has a resinous lustre, and a specific gravity of 2.980. Klaproth found it composed of

Silica	36·5
Boracic acid	24
Lime	35·5
Water	4·
	100·0 †

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* Bergman, iii. 363.

† Gehlen's Journal, vi. 107.

6. Phosphate.

Sp. 6. *Phosphate of lime.* Of this salt there are at least four subspecies, which may be obtained in a separate state. These are the *phosphate*, *biphosphate*, *quadriphosphate*, and *subphosphate*.

Subspecies 1. *Phosphate.* This interesting salt, which constitutes the basis of bones, was pointed out by Scheele and Gahn in 1774; but for the first precise account of its properties we are indebted to Ekeberg,[*] Fourcroy, and Vauquelin.[†]

Preparation.

As this salt constitutes the basis of bones, it is not necessary to prepare it artificially. It may be obtained in a state of purity by the following process: Calcine the bones to whiteness, reduce them to powder, and wash them repeatedly with water, to separate several soluble salts which are present. Dissolve the whole in muriatic acid, and precipitate by means of ammonia. The precipitate, when well washed and dried, is pure phosphate of lime.

Properties.

Phosphate of lime, thus prepared, is always in the state of a white powder. It is destitute of taste, insoluble in water, and not liable to be altered by exposure to the air. It may be exposed to a strong heat without undergoing any change; but in a very violent heat it becomes soft, and is converted into a white semitransparent enamel, or rather porcelain. According to the experiments of Saussure, a heat of 378° Wedgewood is necessary to produce this effect.[‡] It is soluble in nitric and muriatic acid without effervescence, and may be again precipitated from them unaltered by muriate of ammonia.

Sulphuric, nitric, muriatic, fluoric, and several vegetable acids are capable of decomposing phosphate of lime; but the decomposition is only partial.

Constituents.

The following table exhibits the best experiments hitherto made on the composition of this salt:

	§	‖	**
Acid	100	100	100
Lime	72·91	84·53	79·775

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[*] Crell's Annals, 1798, i. 323.

[†] Mem. de l'Instit. ii. 274.

[‡] Jour. de Phys. xlv. 26.

§ Ekeberg, correcting his data. Crell's Annals, 1798, i. 331.

‖ Berzelius, Ann. de Chim. et Phys. ii. 108.

** By my experiments.

Book II.
Division II.

Subspecies 2. *Biphosphate of lime.* If we digest phosphate of lime in pure phosphoric acid dissolved in hot water, the acid will be found to take up a quantity of phosphate containing exactly its own weight of phosphoric acid; but it refuses to dissolve any more. I consider, therefore, this solution as a biphosphate of lime. It has an acid and rather disagreeable harsh taste. When slowly evaporated to dryness, it does not crystallize, but forms a dry white mass, somewhat deliquescent in the air and soluble in water, but not in acids. Before the blow-pipe it melts into a transparent tasteless glass, insoluble in water, and incapable of acting on vegetable blues. No acid dissolves it.

Subspecies 3. *Quadriphosphate of lime.* If phosphate of lime in fine powder be digested for some time with as much sulphuric acid as is capable of saturating the whole of the lime which it contains; if it be then diluted with a sufficient quantity of water and thrown upon a filtre, the liquid which passes through contains the whole of the posphoric acid * still combined with one-fourth of the lime which originally existed in the salt. The other three-fourths have been abstracted by the sulphuric acid, and remain upon the filter. This liquid, therefore, contains, in solution, a quadriphosphate of lime. This is the salt described by Fourcroy and Vauquelin, in 1795, under the name of superphosphate of lime. When evaporated, it forms soft crusts, which have an acid taste, and are soluble in water. When heated, it readily melts before the blow-pipe into a transparent tasteless glass, insoluble in water and acids, and not affecting vegetable blues. This is the well-known substance from which phosphoric acid is made. It is sold by apothecaries under the name of *glassy phosphoric acid.* If it be mixed with a quantity of bicarbonate of potash and exposed to a red heat, it is decomposed and converted into phosphate of potash and common phosphate of lime. By this treatment 22 grains of common phosphate of lime may be obtained from 50 grains of the glassy salt.

Subspecies 4. *Subphosphate of lime.* This salt occurs native, and is known to mineralogists by the name of *apatite* or *asparagus stone.* It is usually crystallized in low six-sided prisms. Its colour varies, but is most commonly white or green. It has a great deal of lustre, which is resinous. Its

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* About a third of the phosphate of lime is not decomposed, but I abstract this quantity.

fracture is imperfectly foliated. It is soft, and its specific gravity varies from 2·824 to 32. According to the analyses of Klaproth and Vauquelin it is composed of

	*	†
Phosphoric acid	100	100
Lime	118·5	125·12

Sp. 7. *Phosphite of lime.* This salt has not yet been examined.

Sp. 8. *Hypophosphite of lime.* This salt is very soluble in water; but its properties have not been particularly examined.

9. Sulphate.

Sp. 9. *Sulphate of lime.* Of this salt there are two subspecies. The first contains water, and is called *common sulphate:* The second, which is destitute of water, is called *anhydrous sulphate.*

Common sulphate.

Subspecies 1. *Common sulphate.* This salt was well known to the ancients under the name of *gypsum;* but the composition of gypsum was not known till Margraff and Macquer analyzed it, and proved it to be a compound of sulphuric acid and lime. The salt formed by the artificial union of these two bodies was formerly called *selenite*, probably from its whiteness.

Properties.

The properties of this salt were first examined with precision by Bergman. It is found abundantly in different parts of the world, so that it is seldom formed artificially. When pure, it is frequently crystallized. The primitive form of its crystals is, according to Haüy, a right angular prism with rhomboidal bases, whose angles are 113° and 67°. Its integrant particles have the same form; but it is more usually found crystallized in octahedrons, in six-sided prisms, with four-sided summits, or lenticular. These crystals are often exceedingly transparent.

It has a slightly nauseous taste, scarcely perceptible, except by drinking a glass of water impregnated with it.‡ It is soluble in 460 parts of water at the temperature of 60,§ and in 450 of boiling water. Mr. Paul has observed, that if this solution be saturated by pressure with hydrogen gas, the sulphate in about six months is converted into a sulphuret.|| The salt is not affected by exposure to the air. It is soluble in sulphuric acid.

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* Vauquelin, Jour. de Min. No. 37. p. 2.

† Klaproth, Beitrage, iv. 194.

‡ Macquer.

§ Bucholz, Gehlen's Journal, v. 165.

|| Phil. Mag. xv. 63.

When heated, it loses its water of crystallization, decrepitates, and falls into a soft white powder. This powder, when its water has been driven off by the application of a red heat, absorbs water very rapidly, and solidifies it; at the same time a slight increase of temperature takes place: so that if it be formed into a paste with water, it dries in a few minutes. In this state, but mixed with a portion of carbonate of lime, it is called *Plaster of Paris*, and is much employed for forming casts, &c. in consequence of this property.

Sulphate of lime, when exposed to a violent heat, melts; before the blow-pipe it gives an opaque vitreous globule. The temperature necessary to produce this effect is, according to Saussure, 51° of Wedgewood.*

The following table exhibits the best experiments hitherto made to ascertain the proportion of the constituents of this salt:

	†	†	‡	§	||	**	††	††
Acid	43	56·58	46	57	57·57	58	57·97	45·8
Lime	33	43·42	32	43	42·43	42	42·03	33·2
Water	24		22					21
	100	100	100	100	100	100	100	100

Anhydrous sulphate.

Subspecies 2. *Anhydrous sulphate.* This subspecies is found native in different parts of the earth; Sweden, Tyrol, Berne, &c. It seems to have been first pointed out by Haüy. A specimen of it was described with much precision by Fleurieu in the Journal de Physique for 1798; and analyzed by Vauquelin, who first ascertained its composition. It has since been described with more accuracy by Bournon,‡‡ and a purer specimen of it analyzed by Chenevix,§§ and more lately by Klaproth.|| ||

It is usually crystallized. The primitive form of its crystals is a rectangular prism, having two of its faces broader than the other two. It has considerable lustre, and the broad faces have the appearance of pearl. Its specific gravity is about 2·960. Its hardness is considerable, being not inferior to that of calcareous spar. It usually phosphoresces when heated.

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* Jour. de Phys. xlv. 16.

† Bucholz, Gehlen's Jour. v. 162.

‡ Bergman, i. 135.

§ By my analysis.

|| Klaproth, Gehlen's Journal, ii. 359.

** Berzelius, Ann. de Chim. lxxvii. 84.

†† Theoretical composition.

‡‡ Jour. de Min. An. x. ii. 345.

§§ Ibid. p. 118.

|| || Gehlen's Jour. ii. 355.

It is transparent, insoluble in water, and in its other properties agrees with common sulphate.

In the proportions of its contituent parts it coincides exactly with common sulphate, excepting in the absence of water.

10. Sulphite.

Sp. 10. *Sulphite of lime.* This salt was first mentioned by Berthollet, and described by Fourcroy and Vauquelin.

When obtained by saturating carbonate of lime by sulphurous acid, it has the form of a white powder; but if an excess of sulphurous acid be added, it dissolves, and crystallizes on cooling in six-sided prisms, terminated by long six sided pyramids. It has scarcely any taste; however, when kept long in the mouth, it communicates to the tongue a taste which is manifestly sulphureous. It requires about 800 parts of water to dissolve it. When exposed to the air it effloresces very slowly, and its surface is changed into sulphate of lime. When heated, it loses its water of crystallization, and falls to powder. A violent heat disengages some sulphur, and converts it into sulphate of lime. Its constituents are

Acid	54·29
Lime	45·71
	100·00

11. Hyposulphite

Sp. 11. *Hyposulphite of lime.* When a solution of sulphuret of lime is exposed to the air it loses its colour in a few days, and some sulphur and carbonate of lime precipitate, which are easily removed by the filter. When the liquid is evaporated, it yields crystals in prisms somewhat similar to the crystals of muriate of lime. These crystals may be preserved in the open air without undergoing any alteration. They are soluble in water, and consist of hyposulphite of lime.*

Mr. Herschell has found that this salt may be obtained in considerable quantity by passing a current of sulphurous acid through the liquid formed by boiling a mixture of flowers of sulphur and quick lime in a sufficient quantity of water. When the liquid is evaporated at a temperature not exceeding 130°, it yields on cooling large and beautiful crystals most commonly in the shape of irregular six-sided prisms, which refract doubly. Water, at the temperature of 37°, dissolves nearly its own weight of this salt, and the temperature falls to 31°. The specific gravity of a solution saturated at 50° is 1·300, and when the specific gravity is 1·114371 at 60°, the

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* Gay-Lussac, Ann. de Chim. lxxxv. 200

solution contains 0·2081 of its weight of the salt. These crystals are not altered by exposure to the air. They are insoluble in alcohol of the specific gravity 0·82344. According to the analysis of Mr. Herschel this salt is a compound of 1 atom lime + 2 atoms hyposulphurous acid + 6 atoms water.* It is therefore a binhyposulphite, and its constituents are

Hyposulphurous acid	36·641	or 6
Lime	22·137	.. 3·625
Water	41·222	.. 6·75
	100·000	

Sp. 12. *Hyposulphate of lime.* This salt forms regular hexahedral plates grouped usually in roses.†

13. Seleniate.

Sp. 13. *Seleniate of lime.* The neutral seleniate is very imperfectly soluble in water. It precipitates by degrees when we dissolve carbonate of lime in selenic acid. It constitutes, when dry, a soft powder very similar to carbonate of lime. When heated to redness it melts, and if the fusion takes place in a glass vessel it corrodes the glass and gradually passes through it.

The *biseleniate* is obtained by dissolving the seleniate in selenic acid. It crystallizes in small prisms which are not altered by exposure to the air. Ammonia deprives it of the half of its acid. Heat produces the same effect.‡

14. Arseniate.

Sp. 14. *Arseniate of lime.* When arsenic acid is dropped into lime water, arseniate of lime is precipitated; but if an excess of acid be added, the salt is redissolved, and yields, when evaporated, small crystals of arseniate of lime, which are insoluble in water, and decomposed by sulphuric acid. This salt may be formed also by dissolving chalk in arsenic acid, or by mixing the alkaline arseniates with the nitrate, muriate, or acetate of lime. Arseniate of lime, when heated, exhibits the same phenomena as arseniate of potash. The constituents of this salt, according to the analysis of Laugier,§ are as follows:

Arsenic acid	67
Lime	33
	100

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* Edin. Philosoph. Jour. i. 14.

† Gay-Lussac, Annals of Philosophy, xiv. 355.

‡ Berzelius, Ann. de Chim. et de Phys. ix. 263.

§ Ann. de Chim. lxxxv. 58.

Supposing it a compound of 1 atom acid + 2 atoms base, it would consist of

Acid	66·6
Lime	33·3
	100

Numbers which coincide with those of Laugier.

Sp. 15. *Arsenite of lime.* A white insoluble powder.

Sp. 16. *Antimoniate of lime.* This salt may be obtained by pouring a solution of antimoniate of potash into muriate of lime. It is a white powder, sparingly soluble in water. The precipitate assumes a crystalline form, precisely like that of carbonate of lime.*

Sp. 17. *Antimonite of lime.* A white crystalline powder, very little soluble in water.†

18. Chromate.

Sp. 18. *Chromate of lime.* This salt has been hitherto examined only by Vauquelin. By evaporation it yields silky plates of a yellowish-brown colour, readily soluble in water. The fixed alkalies decompose it.‡

Sp. 19. *Molybdate of lime.* This salt is obtained in the state of a powder by dropping molybdic acid into the solution of lime in nitric or muriatic acids. It does not appear to be soluble in water.§

20. Tungstate.

Sp. 20. *Tungstate of lime.* This salt is found native, and is known to mineralogists by the name of *tungsten.* It was first described, and gave its name to the metallic oxide and to the whole genus. It is usually crystallized; and from the observations of Bournon, it appears that its primitive form is an octahedron composed of two four-sided pyramids, applied base to base: the faces are isosceles triangles; and the angle at the apex 44° 16′: each of the others 67° 52′. The solid angle at the apex, taken on the faces, is 48°; taken on the edges of the crystal, 64° 22′.‖

It is of a yellowish-grey colour, and sometimes crystallized, and always somewhat transparent. The primitive form of its crystals, according to Haüy, is the octahedron. Its specific gravity is about six, and its hardness is generally considerable. It is insoluble in water, and is not sensibly altered by expo-

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* Berzelius, Nicholson's Jour. xxxv. 41.
† Ibid. 45.
‡ Ann. de Chim. lxx. 70.
§ Gren's Handbuch, iii. 711.
‖ Bournon, Jour. de Min. An. xi. No. 75, p. 161.

sure to heat. According to the analysis of Berzelius,[*] it is composed of

Tungstic acid ...	80·417
Lime	19·4
	99·817

21. Acetate.

Sp. 21. *Acetate of lime.* This salt was first described accurately by Crollius. The ancients, however, used a mixture of lime and vinegar in surgery.[†] It is easily formed by dissolving chalk in acetic acid. When the solution is evaporated till a pellicle forms on its surface, it yields, on cooling, the acetate of lime in fine prismatic needles of a glossy appearance like satin. Its specific gravity is 1·005.[‡]

Its taste is bitter and sour, because it has an excess of acid. It is soluble in water. It is not altered by exposure to the air; at least Morveau kept some of it for a whole year merely covered with paper, and even quite uncovered for a month, without its undergoing any alteration.[§] Heat decomposes it by disengaging and at the same time partly decomposing its acid.

The constituents of this salt, according to the experiments hitherto made, are as follows:

	[‖]	[**]	[††]	[‡‡]	[§§]
Acid......	64·3..	65·11..	65·75..	64·6..	63·75
Base......	35·7..	34·89..	34·25..	35·4..	36·25
Total	100	100	100	100	100

22. Benzoate.

Sp. 22. *Benzoate of lime.* This salt forms white, shining, pointed crystals, of a sweetish taste, much more soluble in hot than in cold water. It exists in abundance in the urine of cows.[‖‖] One hundred parts of cold water dissolve 5 parts of this salt. When heated it melts, gives out water and some benzoic acid. When the heat is increased an empyreumatic acid is separated similar to balsam of Peru.[***]

Sp. 23. *Succinate of lime.* This salt forms oblong, pointed,

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[*] Afhandlingar, iv. 305.

[†] Plinii, lib. xxxvi. c. 24.

[‡] Hassenfratz, Ann. de Chim. xxviii. 12.

[§] Morveau, Encycl. Method. i. 9.

[‖] Higgins on acetous acid, p. 47.

[**] Richter, Statique Chimique, i. p. 136.

[††] Wenzel, p. 150.

[‡‡] Berzelius, Annals of Philosophy, v. 174.

[§§] Theoretical composition.

[‖‖] Fourcroy and Vauquelin.

[***] Bucholz, Gehlen's Journal für die Chemie, Physick, &c. ix. 348.

non-deliquescent crystals, which are difficultly soluble even in boiling water. It is not altered by exposure to the air. It is decomposed by muriate of ammonia, and by the fixed alkaline carbonates.

24. Moroxylate.

Sp. 24. *Moroxylate of lime.* This salt was found on the bark of a mulberry-tree in Naples. It is crystallized in short needles, not altered by exposure to the air. At the temperature of the atmosphere, 100 parts of water dissolve 1½ parts of this salt, and 3½ at a boiling heat. It has a taste resembling succinic acid. When heated, it swells and emits a vapour which irritates the organs of smell. Its solution precipitates acetate of lead, nitrate of silver, and nitrate of mercury.

25. Camphorate.

Sp. 25. *Camphorate of lime.* This salt may be prepared by dropping into lime-water crystallized camphoric acid. The mixture is then to be made boiling hot, passed through a filter, and evaporated to about ¾ths of its volume. On cooling camphorate of lime is deposited. It has no regular shape; but if the evaporation has been properly conducted, it is in plates lying one above another. It is of a white colour, and has a taste slightly bitter.

Water at the temperature of 60° dissolves very little of this salt; boiling water is capable of dissolving about $\frac{1}{200}$th part of its weight of it. It is insoluble in alcohol. When exposed to the air, it dries and falls into powder. When exposed to a moderate heat, it melts and swells up; when placed on burning coals, or when heated in close vessels, the acid is decomposed and volatilized, and the lime remains pure. When sulphuric acid is poured into a solution of this salt, it produces an insoluble precipitate. Nitric and muriatic acids precipitate the camphoric acid.

It is composed, according to Bouillon Lagrange, of

50 acid
43 lime
7 water
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100

Sp. 26. *Boletate of lime.* Described in p. 157 of this vol.

27. Suberate.

Sp. 27. *Suberate of lime.* This salt does not crystallize. It is perfectly white: it has a saltish taste: it does not redden the tincture of turnsole. It is very sparingly soluble in water except when hot; and as the solution cools most of the salt precipitates again. When placed upon burning coals it swells up, the acid is decomposed, and there remains only the lime in the state of powder.*

28. Oxalate.

Sp. 28. *Oxalate of lime.* Oxalic acid does not readily dissolve lime, on account of the insolubility of the oxalate of that base; but the salt may be easily formed by dropping oxalic acid into any of the acid solutions of lime. The oxalate of lime immediately precipitates in the state of a white insipid powder, insoluble in water, and communicating a green colour to the syrup of violets. This salt is in the form of a white powder, tasteless, and perfectly insoluble in water. But it dissolves in almost all acids with considerable facility; of course, it is not precipitated from liquids if they contain an excess of acid. The composition of this salt is as follows:

	†	‡	§	‖	**
Acid	62·5 ..	62 ..	61·345 ..	56·25 ..	55·44
Base	37·5 ..	38 ..	38·655 ..	43·75 ..	44·56
Total	100·0	100	100·000	100·00	100·00

No acid decomposes this salt completely except by destroying the oxalic acid, nor any alkaline or earthy body; but the acid may be easily decomposed and driven off by the action of heat. Oxalate of lime is not rendered soluble by adding an excess of acid. Hence it is probable that no superoxalate of lime exists.

Sp. 29. *Mellate of lime.* When mellitic acid is mixed with a solution of sulphate of lime, very small gritty crystals precipitate, which do not destroy the transparency of the water: but the addition of a little ammonia renders the precipitate flaky.†† The precipitate produced by this acid in lime water is redissolved by the addition of nitric acid.‡‡

30. Tartrate.

Sp. 30. *Tartrate of lime.* This salt may be formed by dissolving lime in tartaric acid, or more economically by dissolving tartar in boiling water, and adding to the solution carbo-

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* Ann. de Chim. xxiii. 53.

† By my analysis.

‡ Berard, Ann. de Chim. lxxiii. 265.

§ Gay-Lussac and Thenard, Recherches Physico-chimiques, ii. 300.

‖ Vogel of Bayreuth, Annals of Philosophy, v. 30.

** Theoretical composition. In all the analyses except Vogel's the oxalic acid still retained a portion of water; of course the proportion of acid is stated in them too high.

†† Vauquelin, Ann. de Chim. xxxvi. 210.

‡‡ Klaproth's Beitrage, iii. 131.

nate of lime in powder till it ceases to produce any efferves- Chap. II. cence, and to redden vegetable blues. Tartrate of lime precipitates in the state of a white powder, tasteless, nearly insoluble in cold water, but soluble in 600 parts of boiling water. It is rendered soluble in water by an excess of acid, or by being mixed with some of the soluble tartrates, as tartar and Rochelle salt. When in the state of a dry powder, it contains a very considerable portion of water, from which it can only be freed by a long exposure to heat. The constituents of this salt are as follows:

	*	†	‡	§
Acid	50·55	69	77·577	69·79
Lime	21·64	31	22·423	30·21
Water	27·81			
	100·00	100	100·000	100·00

The crystals are composed of 1 atom of anhydrous salt + 4 atoms water.

Sp. 31. *Tartrate of potash-and-lime.* This salt was first pointed out by Thenard. It may be formed by pouring lime-water into the solution of tartrate of potash till a precipitate begins to appear, and then allowing the liquid to evaporate spontaneously. The triple salt gradually attaches itself to the sides of the vessel in crystals.[‖]

Sp. 32. *Citrate of lime.* This salt is formed by dissolving 32. Citrate. carbonate of lime in citric acid. It is usually in the state of a white powder scarcely soluble in water; but it is soluble in an excess of acid, and may be obtained from that solution in crystals. The constituents of this salt are as follows:

	**	††	‡‡
Acid	62·66	68·83	67·04
Lime	37·34	31·17	32·96
	100·00	100·00	100·00

Sp. 33. *Kinate of lime.* This salt may be obtained by mace- 33. Kinate.

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[*] Berzelius, Annals of Philosophy, v. 96.

[†] By my analysis.

[‡] Gay-Lussac and Thenard, Recherches Physico-chimiques, ii. 304.

[§] Theoretical composition.

[‖] Ann. de Chim. xxxviii. 32.

[**] Vauquelin, Fourcroy's System, vii. 208.

[††] Gay-Lussac and Thenard, Recherches Physico-chimiques, ii. 306.

[‡‡] Theoretical composition.

rating yellow peruvian bark in water, concentrating the liquid, and setting it aside for spontaneous evaporation.

It is white, crystallizes in square or rhomboidal plates, has no taste, and is flexible under the teeth.

It dissolves in about five times its weight of water of the temperature of 55°. It is insoluble in alcohol.

On burning coals, it swells, giving out the smell of tartar, and leaving a mixture of carbonate of lime and charcoal.

The fixed alkalies and their carbonates precipitate lime from the solution of this salt, but ammonia produces no effect. Sulphuric and oxalic acids precipitate lime likewise; but neither acetate of lead nor nitrate of silver produce any effect.

100 parts of this salt dissolved in water require 22 parts of oxalic acid to precipitate all the lime. The oxalate of lime obtained amounted to 27 parts. Now the lime in 27 parts of oxalate amounts nearly to 17 parts. Hence the salt is composed of

17	lime
83	acid and water.
100	

Sp. 34. *Saclactate of lime.* A white powder insoluble in water.

Sp. 35. *Urate of lime.* A white powder scarcely distinguishable in appearance from uric acid.

36. Malate.

Sp. 36. *Malate of lime.* When malic acid is neutralized with lime, it forms a salt scarcely soluble in water, which may be obtained in crystals, by allowing the supermalate of lime to evaporate spontaneously. Crystals of neutral malate are formed in the solution.* But this acid has a strong tendency to combine in excess with lime, and to form a supermalate of lime. This salt is formed when carbonate of lime is thrown into malic acid, or into any liquid containing it. This supersalt exists in various vegetables, especially the sempervivum tectorum, and some of the sedums.

Supermalate of lime has an acid taste. It yields a precipitate with alkalies, sulphuric acid, and oxalic acid. Lime water saturates the excess of acid, and throws down a precipitate of malate of lime. When the supermalate of lime is evaporated to dryness, it assumes exactly the appearance of gum

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* Scheele, Crell's Annals, ii. 5. Eng. Trans.

arabic; and if it has been spread thin upon the nail or wood, it forms a varnish. It is not so soluble in water as gum arabic, and the taste readily distinguishes the two. Supermalate of lime is insoluble in alcohol.* This salt always reddens vegetable blues.

Sp. 37. *Formate of lime.* A crystallizable salt not altered by exposure to the air.†

38. Lactate.

Sp. 38. *Lactate of lime.* This salt may be obtained by the process described while treating of lactic acid.‡ It is a gummy mass, which, when digested in alcohol, is divided into two portions. 1. A pure lactate of lime is dissolved, and gives a shining varnish inclining to a light yellow colour, which, when slowly dried, cracks all over and becomes opaque. 2. The insoluble portion is a submalate. It is a powder which, by exposure to the air, becomes smooth like gum, or like malate of lime.§ The lactate when sufficiently concentrated forms confused crystals which resemble cauliflower. It is very white, opaque, has little taste, and as it were efflorescing. It dissolves in 21 times its weight of cold water. When heated it melts into a transparent liquid, then swells, blackens, takes fire, and leaves carbonate of lime.‖

Sp. 39. *Gallate of lime.* This salt is soluble in water; but it has not been particularly examined.

Sp. 40. *Tannate of lime.* This salt is insoluble in water, but it has not been particularly examined.

The composition of the salts of lime is easily determined by considering them as composed of 1 atom lime + one atom of each of the acids. An atom of lime weighs 3·625, and the weight of the acids has been given in a preceding chapter.

Of all the salts of lime the carbonate is undoubtedly the most useful. It is from it that all the lime is obtained which is employed in such quantities as a manure, as a cement for building, and for many other well known uses. Next to the carbonate perhaps the sulphate should be placed. It is an excellent manure for clover; is employed as stucco, cut into ornaments, &c. Some of the other salts of lime, as the oxalate, are useful in analyses. The phosphate of lime constitut-

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[*] Scheele, Vauquelin, Ann. de Chim. xxxv. 54.

[†] Margraff's Opusc. i. 310.

[‡] P. 198 of this vol.

[§] Berzelius, Djurkemien, ii. 437.

[‖] Braconnot, Ann. de Chim. lxxxvi. 87.

ing the earth of bones, and existing in animal liquids, is an interesting substance to the physiologist. But the greater number of the salts of lime have not hitherto been applied to any useful purpose whatever.

SECT. X.

SALTS OF BARYTES.

General properties

1. A STILL greater proportion of salts of barytes are insoluble in water than of the salts of lime.

2. They are white or transparent, and in general affect a crystalline form.

3. If a little of the solution of sulphate of soda be let fall into a salt of barytes, a white powder immediately precipitates, which is insoluble in nitric acid.

4. When heat is applied to a salt of barytes, it is not completely dissipated. If the acid be combustible, carbonate of barytes remains behind; if the acid be not combustible or volatile, the salt remains behind undecomposed.

5. Ferrochyazate of potash occasions no precipitate in a salt of barytes; unless the acid happens to contain a metallic basis. The same remark applies to hydrosulphuret of potash when dropped into a salt of barytes.

6. Most of the salts of barytes are poisonous.

1. Nitrate

Sp. 1. *Nitrate of barytes.* This salt was formed immediately after the discovery of barytes. Vauquelin has added considerably to our knowledge of its properties. It is usually prepared by dissolving native carbonate of barytes in nitric acid, or by decomposing sulphuret of barytes by means of nitric acid, and evaporating the filtered solution till the nitrate crystallizes.

Its crystals are regular octahedrons, and often they adhere to each other in the form of stars. The summits of the pyramids are often truncated. Sometimes it crystallizes in three-sided tables with the angles truncated. Sometimes it is obtained in small brilliant plates. Its specific gravity is 2·9149.* It is very easily reduced to powder.

Its taste is hot, acrid, and austere. It is soluble in 12 parts of water at the temperature of 60°, and in about 3 or 4 parts of boiling water. As the solution cools, the salt may be obtained in crystals. It is but little altered by exposure to the

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* Hassenfratz, Ann. de Chim. xxviii, 12.

air. When thrown on burning coals it decrepitates, undergoes a kind of fusion, and then becomes dry. When strongly heated in a crucible, the whole of the acid is gradually driven off, and the barytes remains pure. It detonates less violently with combustibles than most of the other nitrates.

The constituents of this salt have been determined by chemists as in the following table:

Composition.

	*	†	‡	§
Acid	32	38	39	40·91
Base	57	50	61	59·09
Water	11	12		
	100	100	100	100·00

The crystals consist of 1 atom anhydrous salt + 2 atoms water.

Sp. 2. *Nitrite of barytes*. Not examined.

3. Carbonate.

Sp. 3. *Carbonate of barytes*. This salt seems first to have been examined by Bergman. Withering first found it native in 1783. Hence it has received the name of *Witherite*. Since that time it has been examined by Kirwan, Klaproth, Hope, Pelletier, Fourcroy, Vauquelin, and Berzelius, and its properties described with great precision. It may be prepared artificially by exposing barytes water to the open air, or by passing carbonic acid gas into it. In either case the carbonate precipitates in the state of a white powder.

Properties.

It is found native crystallized. Its crystals have been observed to assume four different forms; double six-sided and double four-sided pyramids, six-sided columns terminated by a pyramid with the same number of faces, and small radiated crystals half an inch in length and very thin, appearing to be hexagonal prisms rounded towards the point. It has no sensible taste; yet it is poisonous. Its specific gravity, when native, is 4·331; when prepared artificially, it scarcely exceeds 3·763.

Cold water dissolves $\frac{1}{4304}$ part, and boiling water $\frac{1}{2304}$ part of this salt. Water saturated with carbonic acid dissolves $\frac{1}{830}$ part.|| It is not altered by exposure to the air. It is de-

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* Kirwan, Nicholson's Journal, iii. 215.

† Fourcroy and Vauquelin, Ann. de Chim.

‡ Richter, Statique Chimique, i. 236.

§ Theoretical composition.

|| Fourcroy, Ann. de Chim. iv. 64.

composed by the application of a very violent heat,* either in a black lead crucible, or when formed into a paste with charcoal powder.

The constituents of this salt, according to the experiments of different chemists, are as follows:

Composition.

	†	‡	§	||	**
Acid	20	21·67	22	21·6	22
Base	80	78·33	78	78·4	78
	100	100·00	100	100·0	100

Sp. 4. *Borate of barytes.* An insoluble white powder, which has scarcely been examined, formed by the same process as borate of lime.

Sp. 5. *Silicate of barytes.* No compound of silica and barytes is at present known in the mineral kingdom. But silicate of barytes is easily formed by pouring barytes water into a solution of silicate of potash, silicate of barytes immediately precipitates in the state of a white powder.

6. Phosphite.

Sp. 6. *Phosphate of barytes.* It appears from the late experiments of Berzelius that there are three subspecies of this salt, the *phosphate, biphosphate* and *sesquiphosphate.*

Preparation.

Subspecies 1. *Phosphate.* It may be prepared either by saturating phosphoric acid with barytes or carbonate of barytes, or by mixing together an alkaline phosphate and nitrate or muriate of barytes. In either case the phosphate of barytes precipitates immediately in the form of a white powder.

Properties.

This salt is tasteless, uncrystallizable by art, insoluble in water, and not altered by exposure to the air. Its specific gravity is 1·2867.†† When strongly heated it melts into a grey-coloured enamel.

Its constituents, according to the experiments of Berzelius, are as follows:

	‡‡
Acid	100
Base	214·46

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* Dr. Hope. † Withering.

‡ Aiken, Nicholson's Jour. xxii. 303.

§ Kirwan, Nicholson's Quarto Jour. iii. 215.

|| Berzelius, Ann. de Chim. lxxviii. 29.

** Theoretical composition.

†† Hassenfratz, Ann. de Chim. xxviii. 12.

‡‡ Ann. de Chim. et Phys. ii. 153.

Subspecies 2. *Biphosphate.* Berzelius dissolved phosphate of barytes in phosphoric acid, till the liquid refused to take up any more. The solution being evaporated spontaneously deposited white crystals, which when separated from the liquid resembled crystals of muriate of barytes. They contain water of crystallization. They have a taste similar to that of the muriate, but at the same time acid. This salt reddens vegetable blues. When heated sufficiently it swells into a porous mass like burnt alum. Water decomposes this salt, by dissolving the excess of acid. It contains exactly twice as much acid as the neutral phosphate; or it is composed of 2 atoms acid + 1 atom barytes.*

Subspecies 3. *Sesquiphosphate.* This salt is obtained when a solution of the preceding salt is poured into alcohol. A bulky precipitate falls. When dried it is a light, white, tasteless powder. It is composed of 1½ atom acid + 1 atom of barytes, or, which comes to the same thing, of 3 atoms acid + 2 atoms barytes.†

7. Phosphite.

Sp. 7. *Phosphite of barytes.* Berzelius prepared this salt by pouring muriate of barytes into a solution of phosphite of ammonia. No precipitate appeared at first; but in 24 hours the glass was covered with a crust of phosphite of barytes. When washed and dried, its composition, according to the experiments of Berzelius, was

Phosphorous acid	24·31
Barytes	67·24
Water	8·45
	100·00 ‡

Now if we consider it as a compound of 1 atom phosphorous acid, 1 atom barytes, and 1 atom water, its composition will be

Phosphorous acid	24·35
Barytes...............	67·82
Water................	7·83
	100·00

Sp. 8. *Hypophosphite of barytes.* A very soluble salt, which crystallizes with difficulty.§

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* Berzelius, Ann. de Chim. et Phys. ii. p. 154.

† Ibid. p. 156.

‡ Ann. de Chim. et Phys. ii. 231.

§ Dulong, Ann. de Chim. et Phys. ii. 142.

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9. Sulphate.

Sp. 9. *Sulphate of barytes.* This salt is found abundantly in different parts of the earth, and was formerly denominated *ponderous spar*, from its great weight. Its composition was first ascertained by Gahn.

Properties.

Haüy has shown that the form of its integrant particles is a right-angled prism, whose bases are rombs with angles of 101½° and 78½°. The primitive form of its crystals is the same; but it occurs native in a variety of other forms. It cannot be crystallized by art. This salt is insoluble in water, or at least only soluble in 43000 times its weight of water at the temperature of the atmosphere.[*] Sulphuric acid dissolves it when concentrated and boiling, but it is precipitated by the addition of water.[†]

When suddenly heated, it breaks in pieces and flies about with a crackling noise. This phenomenon, which is called *decrepitation*, is occasioned by the sudden conversion of the water which it contains into steam. When heated very violently it melts, and before the blow-pipe is converted into a white opaque globule. According to Saussure, a heat equal to 35° Wedgewood is required to fuse it.[‡] When formed into a thin cake with flour and water, and heated to redness, it phosphoresces in the dark. This was first observed in a variety of this substance known by the name of Bologna stone. Lemery informs us, that the property was discovered by an Italian shoemaker named Vincenzo Casciarolo. This man found a Bologna stone at the foot of Mount Paterno, and its brightness and gravity made him suppose that it contained silver. Having exposed it to the fire, doubtless in order to extract from it the precious metal, he observed that it was luminous in the dark. Struck with the discovery, he repeated the experiment, and it constantly succeeded with him. It is evident that by the calcination it must be converted, at least partly, into sulphuret.

The following table exhibits the result of the best experiments hitherto made to ascertain the composition of this salt.

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[*] Kirwan's Min. i. 136.

[†] Thus it forms a kind of supersulphate, capable of crystallizing, as Withering first observed. Mr. Hume has also mentioned it in Phil. Mag. xiv. 357. The fact was well known to chemists. This solution, however, is but very imperfectly entitled to the name of supersulphate of barytes; as it parts with its excess of acid at a moderate heat, which by no means is the case with supersulphate of potash.

[‡] Jour. de Phys. xlv. 15.

Composition.

	*	†	‡	§	‖	**
Acid	32	33	33·96	34	32·3	33·9
Base	68	67	66·04	66	67·7	66·1
	100	100	100·00	100	100·0	100·0

10. Sulphite.

Sp. 10. *Sulphite of barytes.* This salt was mentioned by Berthollet: but it was first described by Fourcroy and Vauquelin. When prepared by precipitation, it is in the state of a white powder; but it may be obtained crystallized in opaque needles, or in transparent tetrahedrons with their angles truncated, by dissolving it in sulphurous acid and evaporating slowly. It has but very little taste. Its specific gravity is 1·6938.†† It is insoluble in water.

When heated strongly, sulphur is disengaged, and sulphate of barytes remains. A long exposure to the air is necessary before it is converted into a sulphate. Its constituents are,

	‡‡	§§
Acid	100	100
Base	241·79	243·75
Water	4·91	

Sp. 11. *Hyposulphite of barytes.* This salt may be obtained by pouring muriate of barytes into a concentrated solution of hyposulphite of lime. It falls in the state of a white brilliant scaly powder. It is very slightly soluble in water. When the muriate of barytes is poured into dilute hyposulphite of lime, no precipitate appears at first, but small crystalline grains gradually fall, speedily followed on brisk agitation by a copious separation of the barytes salt. Mr. Herschell, to whom we are indebted for every thing at present known concerning this salt, considers it to be a bihyposulphite.‖‖ Hence its constituents must be

Acid	6
Barytes	9·75
	15·75

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* Vauquelin, Ann. de Chim. l. 168.

† Kirwan and Klaproth, Gehlen, v. 515.

‡ Aiken, Nicholson's Jour. xxii. 304.

§ Fourcroy, iii. 25; and Berzelius, Ann. Chim. lxxviii. 30.

‖ Berard, Ann. de Chim. lxxi. 69.

** Theoretical composition.

†† Hassenfratz, Ann. de Chim. xxviii. 12.

‡‡ Berzelius, Ann. de Chim. lxxvii. 83.

§§ Theoretical composition.

‖‖ Edin. Philos. Jour. i. 20.

Sp. 12. *Hyposulphate of barytes.* This is a soluble salt, which is capable of crystallizing. But its properties have not been described.*

13. Seleniate.

Sp. 13. *Seleniate of barytes.* The neutral salt is a white powder insoluble in water, and not altered by exposure to the heat at which glass melts. It is soluble in the strong mineral acids.

Biseleniate of barytes is obtained by dissolving carbonate of barytes in selenic acid till all effervescence is at an end. It crystallizes in round transparent grains. It is soluble in water. According to the analysis of Berzelius,† the neutral seleniate is composed of

Selenic acid	100
Barytes	137·7

Biseleniate of

Selenic acid	100
Barytes	68

14. Arseniate.

Sp. 14. *Arseniate of barytes.* This salt was formed by Scheele by dissolving barytes in arsenic acid. When the saturation was nearly completed, the salt precipitated in the state of an insoluble powder. It may be formed also by mixing arseniate of potash with nitrate or muriate of barytes. This salt is insoluble in water, except there be an excess of acid. When exposed to a violent heat, it shows a tendency to melt, but is not decomposed.‡ According to Laugier § it is composed of

Arsenic acid	34
Barytes	66

If we suppose it a compound of 1 atom acid + 3 atoms barytes, its constituents must be

Acid	33·14
Barytes	66·86
	100·00

Sp. 15. *Arsenite of barytes.* A white insoluble powder.

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* Gay-Lussac, Annals of Philosophy, xiv. 353.

† Ann. de Chim. et de Phys. ix. 261.

‡ Scheele, i. 163.

§ Ann. de Chim. lxxxv. 58.

16. Antimoniate.

Sp. 16. *Antimoniate of barytes.* This salt may be formed by mixing antimoniate of potash with muriate of barytes. It is a light flocculent white powder quite insoluble in water. It is not altered by exposure to the air; but nitric acid when boiled with it slowly extracts all the barytes.*

Sp. 17. *Antimonite of barytes.* When antimonite of potash is added drop by drop to a boiling solution of muriate of barytes, the antimonite of barytes crystallizes gradually on the side of the vessel, in the form of small white needles of a silky brilliancy. This salt is slightly soluble in water and is not altered by exposure to the air.†

18. Chromate.

Sp. 18. *Chromate of barytes.* This salt has been examined by Vauquelin ‡ and John. § It is easily obtained by dropping chromic acid, or chromate of potash into muriate of barytes. The salt precipitates in the form of a light, yellow, insoluble powder. According to the analysis of Vauquelin, it is composed of

Chromic acid	40·16
Barytes	59·84
	100·00

If we consider it as composed of 1 atom acid + 1 atom barytes, its constituents must be

Chromic acid	40
Barytes	60
	100

Proportions which approach very closely to Vauquelin's analysis.

Sp. 19. *Tungstate of barytes.* An insoluble powder, not examined. ‖

20. Acetate.

Sp. 20. *Acetate of barytes.* This salt may be formed by dissolving barytes or its carbonate in acetic acid, or by decomposing the sulphuret of barytes by that acid. By spontaneous evaporation the acetate crystallizes in fine transparent prismatic needles. Its specific gravity is 1·828.** It has an acid and somewhat bitter taste; it is soluble in water, and does not deliquesce when exposed to the air, but rather effloresces. It

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* Berzelius, Nicholson's Jour. xxxv. 46.

† Ibid. p. 15.

‡ Ann. de Chim. lxx. 70.

§ Annals of Philosophy, iv. 426.

‖ Scheele's Memoires, ii. 90.

** Hassenfratz, Ann. de Chim. xxviii. 12.

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is decomposed by the fixed alkalies,[*] by the alkaline carbonates, and by almost all the sulphates. Hence it is often employed to detect the presence of sulphuric acid in solutions. From the experiments of Bucholz, it appears, that 100 of water at the temperature of 60° dissolve about 88 of this salt, and 96 parts when boiling hot. Pure alcohol dissolves $\frac{1}{100}$ part of its weight while cold, and heat scarcely increases the solvent power of this liquid.[†] The constituents of this salt are as follows;

	‡	§	‖	**
Acid	35	.... 39·98	.... 43·17	.... 39·54
Base	58	.... 60·02	.... 56·83	.... 60·46
Water	7			
Total	100	100·00	100·00	100·00

Sp. 21. *Benzoate of barytes.* This salt crystallizes, is soluble in water, not altered by exposure to the air, but decomposed by heat and by the stronger acids.

Sp. 22. *Succinate of barytes.* This salt, according to Bergman, is difficultly soluble in water. It may be obtained by dropping succinate of ammonia into muriate of barytes. It partly precipitates, and is partly deposited in small crystals on the sides of the vessel.

23. Camphorate.

Sp. 23. *Camphorate of barytes.* In order to prepare this salt, barytes is to be dissolved in water, and camphoric acid added to the solution; the mixture is then to be boiled, and afterwards filtered and evaporated to dryness. Camphorate of barytes does not crystallize; when the evaporation is conducted slowly, the salt is deposited in thin plates one above another, which appear transparent while immersed in the liquor, but become opaque whenever they come into contact with the air. It has very little taste, though it leaves at last upon the tongue a slight impression of acidity mixed with bitterness. Water dissolves only a very small quantity of this salt, boiling water being capable of taking up only $\frac{1}{600}$th part of it. It is not altered by exposure to the air. When exposed to heat, it melts easily, and the acid is volatilized. When

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[*] D'Arcet, Ann. de Chim. lxi. 247.

[†] Beitrage, iii. 102.

[‡] Bucholz, Beitrage, iii. 102.

[§] Richter, Statique Chimique, 136.

[‖] Gay-Lussac and Thenard; Recherches Physico-chimiques, ii. 309.

[**] Theoretical composition.

the heat is considerable, the acid burns with a lively blue flame, which becomes red and at last white.*

Sp. 24. *Boletate of barytes.* This salt contains an excess of acid, crystallizes in white plates, and is but little soluble in water, or even in nitric acid. When thrown on a plate of red hot iron it burns with a red flame and remarkable scintillation, leaving carbonate of barytes.†

Sp. 25. *Suberate of barytes.* This salt does not crystallize. Heat makes it swell up, and melts it. It is scarcely soluble in water except there be an excess of acid. It is decomposed by most of the neutral salts except the barytic salts and the fluate of lime.‡

26. Oxalate.

Sp. 26. *Oxalate of barytes.* When oxalic acid is dropped into barytes water, a white powder precipitates, which is oxalate of barytes. It is insipid and insoluble in water. If an excess of acid be added, the powder is again dissolved, and small needle-form crystals are deposited on the sides of the vessel. These are superoxalate of barytes. The same crystals make their appearance when oxalic acid is dropped into concentrated muriate or nitrate of barytes; but if these solutions are largely diluted with water, no precipitate appears. When the superoxalate of barytes is boiled in water, the excess of acid is removed, and the salt falls down in the state of a white powder.§

The constituents of this salt are as follows:

Oxalic acid	31·62
Barytes	68·38
	100·00

27. Mellate.

Sp. 27. *Mellate of barytes.* When mellitic acid is dropped into acetate of barytes, a flaky precipitate appears, which is dissolved by adding more acid. With muriate of barytes it produces no precipitate; but in a short time a group of transparent needle-form crystals is deposited, consisting most likely of supermellate of barytes.

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* Ann. de Chim. xxvii. 28.

† Braconnot, Ann. de Chim. lxxx. 279.

‡ Ann. de Chim. xxiii. p. 52.

§ Bergman, i. 263. See also Fourcroy and Vauquelin, Mem. de l'Instit. ii. 60. and Darracq, Ann. de Chim. xl. 69.

28. Citrate. Sp. 28. *Tartrate of barytes.* When concentrated solutions of tartrate of potash, and nitrate of barytes, are mixed, a precipitate of tartrate of barytes falls in small granular crystals. They are nearly tasteless, but leave a slight saline impression in the mouth. Water dissolves a very small proportion of these crystals, and acquires the same taste. The residual liquid gradually deposites transparent crystals of tartrate of barytes, in four-sided prisms, with square bases.

28. Citrate. Sp. 28. *Citrate of barytes.* When barytes is added to a solution of citric acid, a flaky precipitate appears, which is at first dissolved again by agitation; but remains permanent when the saturation is complete. The citrate of barytes, thus formed, is precipitated in the state of a white powder; but it gradually assumes the appearance of silky flakes, or forms a kind of vegetation very brilliant and beautiful. It requires a great quantity of water to dissolve it. This salt, according to Vauquelin, is composed of

50	acid crystallized
50	barytes
100*	

If we suppose it a compound of 1 atom acid + 1 atom barytes, its component parts must be

Citric acid	43·06
Barytes	56·94
	100·00

Sp. 30. *Saclactate of barytes.* A white powder insoluble in water.

Sp. 31. *Urate of barytes.* A white powder scarcely distinguishable from uric acid.

Sp. 32. *Malate of barytes.* This salt is similar in its properties to malate of lime, and usually contains an excess of acid; though it may be obtained in the state of a white powder which is perfectly neutral.

33. Formate. Sp. 33. *Formate of barytes.* This salt is readily obtained in crystals. These crystals are transparent, and consist of four-sided oblique angled prisms, terminated in four-sided pyramids. The lustre of these crystals is adamantine. They are

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* Fourcroy, vii. 207.

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not altered by exposure to the air. From the experiments of Gehlen compared with those of Berzelius on formic acid, it appears that these crystals contain no water of crystallization, and that they are composed of 1 atom acid + 1 atom base, or by weight of

Formic acid	32·1
Barytes	67·9
	100·0*

34. Lactate.

Sp. 34. *Lactate of barytes.* This salt may be obtained in the same way as lactate of lime. When evaporated it affords a gummy mass. Alcohol dissolves a portion of this matter, which is neutral lactate. There remains behind a sublactate, which is doughy, and has a browner colour than the neutral salt. The alcohol solution by evaporation leaves a mass nearly colourless, which hardens into a stiff but not brittle varnish. It does not crystallize.†

Sp. 35. *Gallate of barytes.*

Sp. 36. *Tannate of barytes.* The first of these salts is soluble, the second insoluble in water. The gallate cannot be obtained in a solid state. When we evaporate the liquid the acid is decomposed.

The composition of the salts of barytes is easily determined by considering them as compounds of 1 atom barytes with 1 atom of each of the acids. The weight of an atom of barytes is 9·75, and the weight of an atom of each of the acids has been given in a preceding chapter.

Several of the salts of barytes are of considerable importance in chemical experiments, as they afford us the means of separating sulphuric acid completely from solutions. Advantage has been taken of the insolubility of sulphate of barytes to obtain certain substances in an insulated state, which do not yield to other methods of operation. Thus Mr. Porrett, by means of this salt, obtained ferrochyazic acid in a state of purity, and Gay-Lussac, by the same means, was enabled to ascertain the properties of chloric acid.

Some of the salts of barytes were formerly employed in medicine, but the good qualities for which they were recommended

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* Gehlen, Schweigger's Jour. iv. 14.

† Berzelius. Djurkemien, ii. 436.

Book II. Division II. do not seem to have been confirmed by the trials that have been made. At present, therefore, scarcely any of these bodies are applied to any useful purpose connected with domestic economy.

SECT. XI.

SALTS OF STRONTIAN.

General properties. 1. The salts of strontian are in general more soluble than the salts of barytes; but less so than the salts of lime.

2. The greater number of them are capable of assuming a crystallized form; though they are not more given to crystallize than the salts of barytes.

3. Solutions of strontian are precipitated by the sulphates, phosphates, and oxalates.

4. We can distinguish a salt of strontian from a salt of barytes by means of succinate of ammonia. When we drop this salt into a solution of a salt of strontian no precipitate falls; but a precipitate immediately appears if we drop it into a salt of barytes.

5. When a piece of paper dipped into a solution of a salt of strontian is set on fire, it burns with a red flame. But if it be dipped into a salt of barytes, or of lime, it burns with a yellow flame.

6. Salts of strontian are not precipitated by ferrochyazate of potash.

7. Salts of strontian are not poisonous, as is the case with salts of barytes.

1. Nitrate. Sp. 1. *Nitrate of strontian.* This salt was first formed by Dr. Hope; it was afterwards examined by Klaproth and Pelletier; but the most complete description of it was published by Vauquelin about the end of the year 1797.* It may be prepared either by dissolving carbonate of strontian in nitric acid, or by decomposing sulphuret of strontian by means of that acid. The solution is to be evaporated to dryness, redissolved in water, and evaporated slowly till the salt crystallizes.

Properties. Nitrate of strontian crystallizes in six-sided pyramidal dodecahedrons, with their apexes truncated, so as to have the appearance of hexahedral plates with bevelled edges. Sometimes in eight-sided prisms. It is perfectly transparent. Its lustre

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* Jour. de Min. An. vi. 7.

is adamantine. It has a strong pungent cooling taste. Its specific gravity is 3·006. It is soluble in its own weight of water at the temperature of 60°, and in little more than half its weight of boiling water. It is insoluble in alcohol. It is not altered by exposure to the air. It deflagrates on hot coals. Subjected to heat in a crucible, it decrepitates gently, and then melts. In a red heat it boils, and the acid is dissipated. If a combustible substance be at this time brought into contact with it, a deflagration with a very vivid red flame is produced.* It is by means of this decomposition that strontian is obtained in the greatest purity. When a crystal of nitrate of strontian is put into the wick of a candle, it communicates a beautiful purple flame.

Its constituents have been ascertained by different chemists as follows:

Composition.

	†	‡	§	||	**
Acid	31·07	48·4	51·4	50·62	50·94
Base	36·21	47·6	48·6	49·38	49·06
Water	32·72	4			
Total	100·00	100·0	100·0	100·00	100·00

The 4 per cent. of water found by Vauquelin are only mechanically mixed with the salt. Stromeyer is of opinion that there exists another nitrate of strontian, containing water of crystallization, which effloresces when exposed to the air. This would account for Kirwan's analysis which raises the water of crystallization to 32·72 per cent. It would account likewise for Dr. Hope's description of the salt, that it effloresces in dry air. I have never myself happened to meet with nitrate of strontian that contained water of crystallization.

Sp. 2. *Nitrite of strontian.* Unknown.

3. Carbonate.

Sp. 3. *Carbonate of strontian.* This salt was first pointed out as distinct from the carbonate of barytes by Crawford, in 1790; but we are indebted for the first accurate account of it to Dr. Hope. His experiments were confirmed by Klaproth, Pelletier, Fourcroy, and Vauquelin. It has been found native at Strontian in Argyleshire, and at Leadhills in Scotland. It

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* Hope, Edin. Trans. iv. 12.

† Kirwan, Nicholson's Journ. iii. 215.

‡ Vauquelin, Jour. de Min. An. vi. 20.

§ Richter, Statique Chimique, i. 136.

|| Stromeyer, Annals of Philosophy, ix.

** Theoretical composition.

is usually in striated semitransparent masses, which have a greenish tinge.

Properties.

It has no taste. It requires 1536 parts of boiling water to dissolve it.[*] Its specific gravity is about 3·66. It is not altered by exposure to the air. When strongly heated in a crucible, it loses part of its acid; and this decomposition is facilitated by making it into a paste with charcoal powder. According to Saussure, it melts into a transparent glass at the temperature of 226° Wedgewood.[†] When thrown in powder on burning coals, it produces red sparks.

Composition.

Its component parts are as follows:

	‡	§	‖	**	††	‡‡
Acid	30·2	30	30·0	29·687	29·9	29·73
Base	61·2	62	69·5	70·313	70·1	70·27
Water	8·6	8	0·5			
	100·0	100	100·0	100·000	100·0	100·00

Sp. 4. *Borate of strontian.* This salt has only been formed by Dr. Hope. It is a white powder, soluble in about 130 parts of boiling water. The solution turns the syrup of violets green.[§§] It is therefore in a state of a sub-borate.

Sp. 5. *Silicate of strontian.* This salt has not hitherto been examined. It may be obtained by pouring strontian water into a solution of silicate of potash. A white powder precipitates, which is silicate of strontian.

6. Phosphate.

Sp. 6. *Phosphate of strontian.* This salt was first formed by Dr. Hope; but it was more particularly described by Vauquelin in 1797.[‖‖]

It may be formed by dissolving carbonate of strontian in phosphoric acid, or by mixing together nitrate of strontian and phosphate of soda. A white precipitate immediately falls, which is the phosphate of strontian.

Properties.

This salt is tasteless, insoluble in water, and not alterable by exposure to the air. It is soluble in an excess of phosphoric acid; a property which distinguishes it from phosphate of ba-

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[*] Hope, Trans. Edin. iv. 5.

[†] Jour. de Phys. xlv. 24.

[‡] Hope, Trans. Edin. iv. 8.

[§] Pelletier, Ann. de Chim. xxi. 135.

[‖] Klaproth, Beitrage, i. 270; and Kirwan, Nicholson's Jour. iii. 215.

[**] Stromeyer, Annals of Philosophy, ix.

[††] By my experiments.

[‡‡] Theoretical composition.

[§§] Hope, Edin. Trans. iv. 17.

[‖‖] Jour. de Min. An. vi. p. 13.

rytes. Before the blow-pipe it fuses into a white enamel, and at the same time emits a phosphoric light. It is completely decomposed by sulphuric acid, and by no other. The constituents of this salt are as follows:

Composition.

	*	†
Acid	41·24	36·565
Base	58·76	63·435
	100·00	100·000

Sp. 7. *Phosphite of strontian.* Unknown.

Sp. 8. *Hypophosphite of strontian.* A very soluble salt, which crystallizes with difficulty.[‡]

9. Sulphate.

Sp. 9. *Sulphate of strontian.* This salt, for the discovery of which we are indebted to Dr. Hope and Mr. Klaproth, may be composed artificially by dropping sulphuric acid into strontian water; in which case it has the form of a white powder. But it exists abundantly in different parts of the world, usually crystallized in rhomboidal prisms.

Properties.

This salt is tasteless. It is soluble in 3840 parts of boiling water. Sulphuric acid dissolves it readily when assisted by heat, but it is precipitated by the addition of water to the solution.[§] In the greater number of its properties it has a considerable resemblance to sulphate of barytes. The constituents of this salt are as follows:

	‖	**	††	‡‡
Acid	42	43	46	43·48
Base	58	57	54	56·52
	100	100	100	100·00

Sp. 10. *Sulphite of strontian.* Unknown.

11. Hyposulphite.

Sp. 11. *Hyposulphite of strontian.* When a solution of sulphuret of strontian is exposed to the air for a few days it becomes colourless, some sulphur and carbonate of strontian

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[*] Vauquelin, Jour. de Min. Ann. vi. p. 13.

[†] Stromeyer, Annals of Philosophy, ix.

[‡] Dulong, Ann. de Chim. et Phys. ii. 142.

[§] Hope, Trans. Edin. iv. 10.

[‖] Klaproth, Beitrage, ii. 97. Clayfield, Nicholson's Quarto Journal, iii. 39. Henry, Ibid. p. 137. Kirwan, Ibid. p. 215.

[**] Stromeyer, Annals of Philosophy, ix.

[††] Vauquelin, Jour. de Min. Ann. vi. 6.

[‡‡] Theoretical composition.

being deposited. When this deposite is removed by the filter, the clear liquid yields by evaporation fine transparent rhomboidal crystals somewhat flattened. These crystals are not altered by exposure to the air at the temperature of 77°; but at 122° they effloresce like sulphate of lime when calcined. They still continue unaltered, excepting the loss of their water of crystallization. At the temperature of 50° water dissolves the sixth part of its weight of this salt.*

Mr. Herschell formed this salt by passing a current of sulphurous acid through hydroguretted sulphuret of strontian. Its taste is purely bitter. It dissolves in about $1\frac{3}{4}$ times its weight of hot water. It is insoluble in alcohol. It dissolves chloride of silver with great facility. When heated, it becomes white, without losing its figure, and burns with a very faint flame.†

Sp. 12. *Hyposulphate of strontian.* This salt crystallizes in small six-sided plates, whose edges are internally inclined contrary ways, similar to those which would be formed in an octahedron, by sections parallel to two of its opposite faces.‡

13. Seleniate. Sp. 13. *Seleniate of strontian.* The neutral seleniate is a white insoluble powder. Biseleniate is obtained by dissolving carbonate of strontian in selenic acid. When slowly evaporated, the salt is deposited in the state of a white crust, very difficultly soluble in water, even at a boiling temperature. When heated, it melts, gives out its water of crystallization, swells, and forms a porous mass, from which the heat gradually separates the excess of acid. The neutral seleniate does not liquify when heated.§

Sp. 14. *Arseniate of strontian.* A white insoluble powder obtained by pouring arsenic acid, or arseniate of soda into nitrate or muriate of strontian. It dissolves readily in nitric acid. If we believe Moretti arsenic acid separates strontian from sulphuric acid.‖

Sp. 15. *Arsenite of strontian.* This salt is soluble in water, but does not crystallize. Arsenious acid occasions no precipitate in strontian water.**

Sp. 16. *Chromate of strontian.* This salt is insoluble. When

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* Gay-Lussac, Ann. de Chim. lxxxv. 199.

† Edin. Philos. Jour. i. 20

‡ Gay-Lussac, Annals of Philosophy, xiv. 355.

§ Berzelius, Ann. de Chim. et de Phys. ix. 263.

‖ Ann. de Chim. lxxxvi. 267.

** Moretti, ibid. 269.

carbonate of strontian is thrown into chromic acid a yellow powder is formed, which is chromate of strontian. Probably it would be most easily procured by double decomposition.*

17. Acetate.

Sp. 17. *Acetate of strontian.* This salt, which was first examined by Dr. Hope, and afterwards by Vauquelin, is easily formed by dissolving strontian or its carbonate in acetic acid. By evaporation it is obtained in large crystals, which are flat rhomboidal prisms, with two of the edges truncated. They effloresce in the air. Forty-nine parts of this salt are soluble in 120 parts of boiling water; it seems to be nearly as soluble in cold water. It renders vegetable colours green.† Its taste is not unpleasant. When heated, its acid is decomposed, as happens to all the other acetates. Its constituents are

	‡	§
Acid	52·69	49·53
Base	47·31	50·47
	100·00	100·00

Sp. 18. *Benzoate of strontian.* As benzoate of ammonia occasions no precipitation when dropped into muriate of strontian, it is probable that benzoate of strontian is soluble in water.

19. Succinate.

Sp. 19. *Succinate of strontian.* This salt may be formed by saturating strontian water with succinic acid. When the solution is evaporated the succinate of strontian precipitates in small crystals as fine as sand. The taste of this salt has some resemblance to that of muriate of potash. It is equally soluble in hot and in cold water. When a little of it is dropped into barytes water, succinate of barytes immediately precipitates.||

20. Oxalate.

Sp. 20. *Oxalate of strontian.* This salt, first examined by Dr. Hope and afterwards by Vauquelin, may be readily formed by mixing together a solution of oxalate of potash and nitrate of strontian. The oxalate of strontian immediately precipitates. It is a white insipid powder; soluble in 1920 parts of boiling water. Heat decomposes it by destroying the acid.**

The constituents of this salt are as follows:

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* John, Annals of Philosophy, iv. 426.

† Hope, Trans. Edin. iv. 14.

‡ Richter, Statique Chimique, i. 136.

§ Theoretical composition.

|| Moretti, Ann. de Chim. lxxxvi. 270.

** Hope, Edin. Trans. iv. 14.

	*	†	‡
Acid	45·54	39·77	40·96
Base	54·46	60·23	59·04
	100·00	100·00	100·00

There exists also a binoxalate of strontian. It is soluble in water, and contains exactly twice as much acid as the preceding salt. The excess of acid is very easily separated from it.

21. Tartrate.

Sp. 21. *Tartrate of strontian.* This salt, first examined by Dr. Hope, and afterwards by Vauquelin, may be formed by dissolving strontian in tartaric acid, or by mixing together solutions of nitrate of strontian and tartrate of potash. Its crystals are rhomboidal prisms, with angles of 60° and 120°. It is insipid. It dissolves in 320 parts of boiling water. It is composed of

	§	‖
Acid	47·12	56·3
Base	52·88	43·7
	100·00	100·0

22. Citrate.

Sp. 22. *Citrate of strontian.* This salt was obtained by Vauquelin by mixing a solution of citrate of ammonia with nitrate of strontian. No precipitate appears; but when the liquid is slowly evaporated, small crystals of citrate of strontian are gradually formed. This salt is soluble in water, and exhibits nearly the same properties as the oxalate or tartrate of strontian.**

Sp. 23. *Urate of strontian.* A white insoluble powder, scarcely distinguishable in appearance from uric acid.

Sp. 24. *Malate of strontian.* Malic acid occasions no precipitate in strontian water. Hence it follows, that malate of strontian is more soluble than malate of barytes.††

25. Lactate.

Sp. 25. *Lactate of strontian.* Lactic acid dissolves carbonate of strontian disengaging the carbonic acid. The solution when concentrated by evaporation assumes the form of mucilage; but in 24 hours it becomes solid, has a whitish co-

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* Berard, Ann. de Chim. lxxiii. 286.

† By my analysis.

‡ Theoretical composition.

§ Vauquelin, Jour. de Min. An. vi. p. 15.

‖ Theoretical composition.

** Jour. de Min. An. vi. p. 16.

†† Pelletier, Ann. de Chim. xxi. 141.

lour, is semitransparent, and consists of a congeries of globular bodies resembling the form which malate of lime assumes. At the temperature of about 70°, this salt is soluble in eight times its weight of water.*

Such are the properties of the salts of strontian, as far as they have been examined. But from the preceding enumeration it is obvious that they have been but superficially studied, and that about one third of the whole genus still remains unknown.

Their composition is easily determined by considering them as composed of 1 atom of strontian united to 1 atom of each of the acids. The weight of an atom of strontian is 6·5, and that of each of the acids has been given in a preceding chapter of this volume.

None of the salts of strontian has hitherto been applied to any purpose useful in domestic œconomy.

SECT. XII.

SALTS OF MAGNESIA.

The salts of magnesia can scarcely be said to have been known till Dr. Black published his celebrated experiments on magnesia alba and quicklime, in the year 1755. They were afterwards examined more in detail by Bergman, and different salts of magnesia have been since described by different chemists.

General properties.

1. A very great proportion of them is soluble in water, and capable of crystallizing.

2. When any of the alkalies or of their carbonates is dropped into a salt of magnesia a white flocky precipitate falls.

3. No precipitate appears when sulphate of soda is dropped into a salt of magnesia.

4. If phosphate of soda be dropped into a salt of magnesia, no precipitate appears; but if any ammonia be added, a white precipitate falls, which is a triple salt composed of phosphoric acid, ammonia, and magnesia. This precipitation furnishes the best method yet known for separating magnesia from other bodies, and determining its quantity. It was first pointed out by Dr. Wollaston.

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* Braconnot, Ann. de Chim. lxxxvi. 87.

5. Ferrochyazate of potash occasions no precipitate in a salt of magnesia, unless the acid happen to have a metal for its basis.

6. Magnesia has a greater tendency than any of the bases whose salts have been already described to enter into triple compounds. The base with which it is most given to unite is ammonia.

1. Nitrate.

Sp. 1. *Nitrate of magnesia.* The composition of this salt was first ascertained by Dr. Black. Bergman is the only chemist who has given a detailed description of it. It is usually prepared by saturating nitric acid with magnesia, and evaporating to a proper consistency. The salt crystallizes as the solution cools. It crystallizes in rhomboidal prisms, and often in small needles attached to one another. Its taste is very bitter and disagreeable. Its specific gravity is 1·736.[*]

Properties.

At the temperature of 60° it is soluble in little more than its weight of water, and still more soluble in boiling water. Alcohol of about 0·840 dissolves $\frac{1}{9}$th of its weight of it.[†] When exposed to the air it gradually attracts moisture and deliquesces. When heated, it undergoes the watery fusion; and when its water is evaporated, it assumes the form of a dry powder. In a strong heat it gives out a little oxygen gas, then nitrous gas, and lastly nitrous acid; and the earth remains behind in a state of purity.[‡] It scarcely detonates with any of the combustible bodies.

The following table exhibits the constituents of this salt according to the analyses of different chemists:

Composition.

	§	‖	**	††	‡‡
Acid	43	46	69·6	72	72·97
Base	27	22	30·4	28	27·03
Water	30	32?			
	100	100	100·0	100	100·00

Sp. 2. *Nitrite of magnesia.* Unknown.

3. Ammonio nitrate.

Sp. 3. *Ammonio-nitrate of magnesia.* This salt was first described by Fourcroy in 1790. It may be prepared by mixing together the solutions of nitrate of ammonia and nitrate of

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[*] Hassenfratz, Ann. de Chim. xxviii. 12.

[†] Bergman, i. 136.

[‡] Wenzel, p. 85.

[§] Bergman, i. 136.

[‖] Kirwan, Nicholson's Jour. iii. 215.

[**] Richter, Statique Chimique, p. 136.

[††] Wenzel, p. 85.

[‡‡] Theoretical composition.

magnesia, or by decomposing either of these salts in part by the base of the other. When the two salts are mixed together, the nitrate of ammonia and magnesia gradually precipitate in crystals.

Properties.

These crystals are in the form of fine prisms. They have a bitter, acrid, ammoniacal taste. They are soluble at 60° in about 11 parts of water; but boiling water dissolves a greater proportion of them. When exposed to the air, they gradually attract moisture; but much more slowly than either of their component parts. The phenomena which this compound exhibits when heated are similar to those which its component parts exhibit in like circumstances. According to Fourcroy, is is composed of

78 nitrate of magnesia
22 nitrate of ammonia

100*

4. Carbonate.

Sp. 4. *Carbonate of magnesia.* This salt has been long known. Its composition was first discovered by Dr. Black; afterwards its properties were investigated by Bergman and Butini, and more lately by Fourcroy.† There are two subspecies of it: the first neutral; the second containing an excess of base.

Preparation.

It is usually prepared by mixing together the solutions of sulphate of magnesia and carbonate of potash, and applying heat. The carbonate of magnesia precipitates in the state of a white powder. Such is the state in which it occurs in commerce; but Fourcroy has shown that in that state it is not saturated with acid. It is therefore only a carbonate; but it may be saturated with acid by diffusing it in water, and making carbonic acid gas pass through it till it be saturated and dissolved.

The bi-carbonate, thus formed, yields by evaporation crystals which are transparent hexagonal prisms terminated by a hexagonal plane: these are partly in groups and partly solitary: their length is about six lines, their breadth two.‡ But it may be obtained in more regular crystals, by mixing together 125 parts of sulphate of magnesia and 136 parts of carbonate of soda, both dissolved in water, filtering the solution,

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* Ann. de Chim. iv. 215.
† Ibid. ii. 278.
‡ Butini, sur le Magnesie.

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and then setting it aside. In two or three days the carbonate of magnesia crystallizes.

Properties.

This salt has little taste. Its specific gravity, when in powder, is only 0·2941 according to Hassenfratz.* It is soluble, when crystallized, in 48 parts of cold water; but when in powder, it requires at least ten times as much; and what is very remarkable, it is more soluble in cold than in hot water impregnated with carbonic acid.† When exposed to the air, it effloresces, and falls into powder.‡ When heated, it decrepitates, falls into powder, and is decomposed.

The constituents of this salt are as follows:

	§	‖
Acid	50	68·75
Base	25	31·25
Water	25	
	100	100·00

I have never met with carbonate of magnesia in commerce. But it exists abundantly in the magnesian lime-stone of England. The magnesia of commerce probably varies considerably in its composition. I have found it composed as follows:

Carbonic acid	14·0	or 1 atom
Magnesia	51·4	4 atoms
Water	28 0	5 atoms
Sulphate of lime	6·6	
	100·0	

Sulphate of lime seems a very common ingredient in it.

5. Borate.

Sp. 5. *Borate of magnesia.* Bergman formed this salt by dissolving magnesia in boracic acid. The solution proceeded slowly; and on evaporation, the salt was precipitated in small irregular crystals. It is soluble in acetic acid. Alcohol decomposes it. It melts easily in the fire without being decomposed.** This salt has been found native in the mountain of Kalkberg near Luneburg in Germany. It was first analyzed by Westrumb in 1788.

Found native.

It is in the form of transparent or opaque white crystals, consisting of cubes, having their edges and four of their angles

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* Ann. de Chim. xxviii. 12.

† Butini.

‡ Fourcroy, Ann. de Chim. ii. 298.

§ Fourcroy and Kirwan.

‖ Theoretical composition.

** Bergman, i. 386.

truncated. It is so hard as to scratch glass, and to strike fire with steel. Its specific gravity is 2·566. When heated, it becomes electric; and, what is singular, the truncated angles are always positively electric, while the opposite entire ones are negative.*

These crystals are insoluble in water, and not altered by exposure to the air. When heated, they decrepitate: in a red heat they lose their lustre, but do not sensibly diminish in weight. In a white heat they lose 0·005 of their weight. When exposed to the action of a very violent heat, they melt into a yellow-coloured glass.

According to Westrumb, they are composed of

73·5	acid
14·6	magnesia
11·9	lime
100·0	

Hence the salt was considered as a triple compound of boracic acid, lime, and magnesia; but Vauquelin has shown, that the lime is foreign, and that the mineral is borate of magnesia.†

Sp. 6. *Silicate of magnesia.* This salt has not been hitherto examined. It is very probable that 2 parts of silica and 2·5 parts of magnesia when properly mixed and heated would constitute a beautiful porcelain. The mass is adhesive, beautiful, and very difficultly fusible.

7. Phosphate.

Sp. 7. *Phosphate of magnesia.* This salt was first formed by Bergman in 1775.‡ It has been examined with much care by the indefatigable Vauquelin.§ It is usually prepared by dissolving carbonate of magnesia in phosphoric acid, and evaporating the solution gradually till the salt crystallizes; but it may be obtained in large regular crystals by a much easier process, first pointed out by Fourcroy. Mix together equal parts of the aqueous solutions of phosphate of soda and sulphate of magnesia. No apparent change takes place at first; but in a few hours large transparent crystals of phosphate of magnesia make their appearance in the solution.

Preparation.

Its crystals are six-sided prisms, the sides of which are unequal. It has very little taste; however, it leaves a cooling and sweetish impression upon the tongue. Its specific gravity is

Properties.

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* Hauy, Ann. de Chim. ix. 59.

† Nicholson, ii. 120, Second Series.

‡ Opusc. i. 390.

§ Jour. de l'Ecole Polytechnique.

1·5489.* It requires about 15 parts of cold water to dissolve it. It is more soluble in boiling water, but it crystallizes in part as the solution cools. When exposed to the air, it loses its water of crystallization, and falls down in powder. When heated moderately, it is also reduced to a dry powder. In a high temperature, it melts into a transparent glass.

Sp. 8. *Ammonio-phosphate of magnesia.* This salt was first discovered by Fourcroy, who found it in a calculous concretion formed in the colon of a horse. Since this discovery, Fourcroy and Vauquelin have observed it also in human urine.

It might be prepared by mixing together solutions of the phosphates of ammonia and of magnesia in water; the triple salt immediately precipitates in the state of a white powder. When urine is allowed to remain a considerable time in close vessels, it often deposites this salt in regular crystals on the sides and bottom of the vessel. These crystals are small four-sided prisms, terminated by irregular four-sided pyramids. This salt is tasteless, scarcely soluble in water, and not liable to be altered by exposure to the air. When heated, it falls to powder, gives out its ammonia, and in a high temperature melts into a transparent globule. When distilled along with charcoal, phosphorus is obtained. Fourcroy has ascertained that the phosphate of ammonia and magnesia, obtained from the calculous concretions of the horse, is composed of

33	phosphate of ammonia
33	phosphate of magnesia
33	water
99	

Sp. 9. *Phosphite of magnesia.* Not examined.

Sp. 10. *Hypophosphite of magnesia.* Not examined.

11. Sulphate.

Sp. 11. *Sulphate of magnesia.* This salt is held in solution in the springs at Epsom in England, and was procured from them by evaporation more than a century ago. Hence the term *Epsom salt*, by which it was long distinguished. Some account of it was given by Grew in 1675; and in 1723, Mr. Brown published a description of the process employed in extracting it from the springs, and in purifying it.† In Italy it is manufactured from shistose minerals, containing sulphur and magnesia. By roasting these minerals, and then moistening them and exposing them to the air, the salt effloresces on

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Phil. Trans. xxxii. 348.

their surface. By solution in water, with the addition of a little lime to precipitate any metallic substance that may be in solution, and repeated crystallizations, the salt is obtained in a state of purity.[*]

It exists in considerable quantity in sea-water; and the uncrystallized residuum in the salt pans, after all the common salt has crystallized, consists partly of this salt dissolved in water. This residuum is usually called *bittern*, and sometimes in Scotland *spirit of salt*.

Properties.

Sulphate of magnesia crystallizes in quadrangular prisms, whose planes are equal, surmounted by quadrangular pyramids, or by dihedral summits. The primitive form of its crystals is, according to Haüy, a four-sided prism, whose bases are squares. The form of its integrant particles is a three-sided prism, whose bases are rectangular isosceles triangles.[†] The crystals are doubly refrangent.

It has an intensely bitter taste. Its specific gravity is 1·66.[‡] At the temperature of 60° it is soluble in its own weight of water, and in less than two-thirds of its weight of boiling water.[§] The volume of water is increased $\frac{4}{10}$ths by adding the salt.[‖] When exposed to the air it effloresces, and is reduced to powder. When exposed to heat it undergoes the watery fusion; and by increasing the temperature its water is evaporated, but it cannot be decomposed by means of heat. Before the blow-pipe it melts with difficulty into an opaque vitreous globule.[**]

The following table exhibits the result of the experiments of different chemists to determine the proportions of the constituents of this salt:

Composition.

	††	‡‡	§§	‖‖	***	†††	‡‡‡
Acid	29·35	30·64	32	33	38	66·64	66·6
Base	17	16·86	19	19	18	33·36	33·3
Water	53·65	52·50	49	48	44		
	100·00	100·00	100	100	100	100·00	100 0

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[*] Ann. de Chim. xlviii. 80. See also Gehlen's Jour. iii. 549. An account of the manufactory has been published by Dr. Holland in Phil. Trans. 1816, p. 294.

[†] Traite de Mineralogie, ii. 322.

[‡] Hassenfratz, Ann. Chim. xxviii. 12.

[§] Bergman, Opusc. i. 135.

[‖] Bergman, Opusc. i. 377.

[**] Bergman, Opusc. i. 377.

[††] Kirwan, Nicholson's Quarto Jour. iii. 215.

[‡‡] Wenzel, p. 62.

[§§] Mojon, Ann. de Chim. xlviii. 81.

[‖‖] Bergman, i. 135.

[***] Henry and Dalton; Dalton's New System of Chemistry, ii. 513.

[†††] Berzelius, Ann. de Chim. lxxxii. 8.

[‡‡‡] Theoretical composition.

Sp. 12. *Ammonio-sulphate of magnesia.* This salt was pointed out by Bergman; but Fourcroy was the first chemist who examined its properties.* It may be prepared by mixing together saturated solutions of sulphate of ammonia and of magnesia. Crystals almost immediately precipitate, which consist of the two salts combined together. Or it may be prepared by pouring ammonia into a solution of sulphate of magnesia. Part only of the magnesia is precipitated. This is to be removed by filtration; and on evaporating the solution, the compound salt is obtained in crystals.

This salt crystallizes in octahedrons. Its taste is acrid and bitter. Its specific gravity is 1·696.† It is less soluble in water than either of its component parts. When heated it undergoes the watery fusion; and if the heat be increased, it is decomposed. It is not altered by exposure to the air.

Composition.

It is composed, according to the analysis of Fourcroy, of

68	sulphate of magnesia
32	sulphate of ammonia
100	

Sp. 13. *Sulphate of potash-and-magnesia.* This salt was first described by Link. He formed it by saturating supersulphate of potash with magnesia. Berthollet formed the same salt by mixing together equal solutions of sulphate of potash and muriate of magnesia, and evaporating the mixture. Crystals of sulphate of potash, with a little muriate of magnesia, are first obtained, and then the triple salt in rhomboidal crystals, which are not altered by exposure to the air. Their solubility is nearly the same as that of sulphate of potash.‡

Composition.

The taste of this salt is bitter. It is composed of

3	parts sulphate of potash
4	parts sulphate of magnesia
7§	

Sp. 14. *Soda-sulphate of magnesia.* This salt was first described by Link, in 1796.‖ It has been lately announced and analysed by Dr. Murray,** who does not appear to have been

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* Ann. de Chim. iv. 21.

† Hassenfratz, Ann. de Chim. xxviii. 121.

‡ Mem. de l'Instit. iii. 218.

§ Link, Crell's Annals, 1796, i. 30.

‖ Crell's Annals, 1796, i. 30.

** Edin. Trans. viii. p. 233.

aware of the previous experiments of the German chemist. Link obtained it by saturating bisulphate of soda with magnesia, and crystallizing the solution. Dr. Murray observed it formed in the boilers of the manufacturers of sulphate of magnesia from the bittern of sea salt. The impure sulphate of magnesia first obtained is re-dissolved in water and crystallized. A fresh quantity is added to the residual liquor, and by the necessary evaporation and cooling, a fresh crop of crystals is obtained. This is repeated a third and fourth time. It is in these last crystallizations that the triple salt is produced, forming frequently in considerable quantities, and precipitating even in the boilers. It is at first irregular and semitransparent; but by solution in water, and a second crystallization, it may be obtained in pretty regular transparent rhombs, truncated on their angles and edges. These crystals are not altered by exposure to the air. They have a bitter taste. At 60° they dissolve in about thrice their weight of water. When heated they do not melt but decrepitate. Their composition according to the experiments of Link and Dr. Murray are as follows:

Composition.

	*	†	‡
Sulphate of magnesia	54	32	32·38
Sulphate of soda	45	39	38·72
Water		28	29·00
	99	99	100·00

15. Sulphite.

Sp. 15. *Sulphite of magnesia.* This salt has only been examined by Fourcroy and Vauquelin. It is prepared, like the others, by saturating carbonate of magnesia with sulphurous acid; a violent effervescence takes place, and the liquid becomes warm. The sulphite as it forms remains at the bottom in the form of a white powder: but if an excess of acid be added, it dissolves, and may be obtained in crystals by subsequent exposure to the air. Its crystals are white and transparent and in the form of depressed tetrahedrons. Its specific gravity is 1·3802.§ Its taste is mild and earthy at first,

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[*] Link, Crell's Annals, 1796, i. 30.

[†] Murray, Edin. Trans. viii. 294.

[‡] Theoretical composition, on the supposition that it is composed of
1 atom sulphate of magnesia
1 atom sulphate of soda
6 atoms water.

[||] Hassenfratz, Ann. de Chim. xxviii. 12.

and afterwards sulphureous. It becomes opaque when exposed to the air; but is very slowly converted into a sulphate. At the temperature of 60° it is soluble in 20 parts of water. Boiling water dissolves a greater proportion of it; but the solution crystallizes on cooling. When its solution in water is exposed to the air, this salt is very soon converted into a sulphate. By exposure to heat, it softens, swells up, and becomes ductile like gum, and loses 0·45 parts of its weight. In a strong heat the acid is disengaged, and the earth remains pure.

Sp. 16. *Ammonio-sulphite of magnesia.* This salt has only been mentioned by Fourcroy. It may be formed by mixing together the solution of sulphite of ammonia and sulphite of magnesia, or by pouring ammonia into the sulphite of magnesia. Its crystals are transparent, but the figure has not been determined. It is less soluble in water than either of its component parts. When exposed to the air, it is gradually converted into sulphate.

17. Hyposulphite.

Sp. 17. *Hyposulphite of magnesia.* This salt is easily obtained by boiling a solution of sulphite of magnesia and flowers of sulphur. It has an intensely bitter taste, is very soluble in water, but does not deliquesce when exposed to the air. It readily crystallizes in cooling. When laid on a hot iron it burns with a blue flame, but is incapable of maintaining combustion pure. Before the flame of the blowpipe it swells into a fungous mass by the escape of the acid precisely as borax does by that of water. Pure magnesia remains behind.*

18. Seleniate.

Sp. 18. *Seleniate of magnesia.* Selenic acid decomposes carbonate of magnesia and forms a crystalline matter, which dissolves in boiling water and deposites crystals in the form of small prisms or four-sided tables. When heated it gives out its water of crystallization, and becomes similar to enamel. It does not melt, nor is it decomposed when heated to redness; but it attacks glass and gradually makes its way through it.

Biseleniate is obtained by dissolving the seleniate in selenic acid and pouring alcohol into the solution. The biseleniate precipitates in the form of a pulpy and coherent mass which attracts moisture from the atmosphere, is soluble in water, but does not yield crystals.†

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* Herschel, Edin. Phil. Jour. i. 21.

† Berzelius, Ann. de Chim. et de Phys. ix. 264.

19. Arseniate.

Sp. 19. *Arseniate of magnesia.* Magnesia dissolves in arsenic acid; but when the acid is nearly saturated, the solution becomes thick and coagulates. The coagulum redissolves in an excess of acid, and yields when evaporated an incrystallizable gummy mass. This salt may be obtained also by mixing the alkaline arseniates with nitrate, muriate, or acetate of magnesia. When heated, it exhibits the same phenomena as arseniate of potash.* It dissolves in nitric acid.

20. Chromate.

Sp. 20. *Chromate of magnesia.* This salt has been hitherto examined only by Vauquelin. It has a fine topaz yellow colour, crystallizes in transparent six-sided prisms, and is very soluble in water. When in large masses it has an orange yellow colour. The magnesia is precipitated by the fixed alkalies and alkaline earths.†

Sp. 21. *Molybdate of magnesia.* This salt, according to Heyer, is soluble in water, has a bitter taste, and does not crystallize.‡

22. Tungstate.

Sp. 22. *Tungstate of magnesia.* When the yellow oxide of tungsten is boiled with carbonate of magnesia, the liquid yields, when evaporated, tungstate of magnesia in small brilliant scales. It is soluble in water, not altered by exposure to the air, and has a taste similar to that of the other species of tungstates. When an acid is dropped in, a white powder or triple salt precipitates.

23. Acetate.

Sp. 23. *Acetate of magnesia.* This salt may be formed by dissolving magnesia or its carbonate in acetic acid. It is not crystallizable; but forms by evaporation a viscid mass.§ It has a sweetish taste: leaving, however, a sense of bitterness.|| Its specific gravity is 1·378.** It is very soluble both in water and alcohol.†† When exposed to the air, it deliquesces. Heat decomposes it.

The constituents of this salt are as follows:

	‡‡	§§	||||
Acid	65·96	70·65	71·83
Base	34·04	29·35	28·17
	100·00	100·00	100·00

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[*] Scheele, i. 159.

[†] Ann. de Chim. lxx. 70.

[‡] Gren's Handbuch, iii. 711.

[§] Bergman, i. 388.

[||] Morveau, Encycl. Method. i. 9.

[**] Hassenfratz, Ann. de Chim. xxviii. 12.

[††] Bergman, i. 388.

[‡‡] Wenzel, p. 150.

[§§] Richter, Statique Chimique, i. 136.

[||||] Theoretical composition.

Sp. 24. *Benzoate of magnesia.* This salt forms feather-shaped crystals of a sharp bitter taste, and easily soluble in water.

25. Succinate.

Sp. 25. *Succinate of magnesia.* This salt has the form of a white, glutinous, frothy mass, which when dried by the fire attracts moisture from the air, and deliquesces.

Sp. 26. *Camphorate of magnesia.* This salt may be prepared by mixing water with carbonate of magnesia, and adding crystallized camphoric acid: heat is then applied, the solution is filtrated, and evaporated to dryness. The salt obtained is dissolved in hot water, passed through a filter, and evaporated by means of a moderate heat till a pellicle forms on the surface of the solution. On cooling the salt is deposited in thin plates. The second solution is intended to remove any excess of magnesia that may happen to be present.

This salt does not crystallize. It is white, opaque, and has a bitter taste. It is scarcely more soluble in water than camphorate of lime. Alcohol has no action on it while cold; but when hot it dissolves the acid and leaves the magnesia, and the acid precipitates again as the alcohol cools. When exposed to the air it dries, and becomes covered with a little powder; but this effect is produced slowly, and only in a warm place. When this salt is placed on burning coals, the acid is volatilized, and the magnesia remains pure. Before the blow-pipe it burns, like the other camphorates, with a blue flame. The nitrates, muriates, and sulphates, do not completely decompose this salt, if we except the nitrate of lime and muriate of alumina.*

Sp. 27. *Suberate of magnesia.* This salt is in the form of a powder: it reddens the tincture of turnsole: it has a bitter taste; it is soluble in water, and attracts some moisture when exposed to the air. When heated it swells up and melts; before the blow-pipe the acid is decomposed, and the magnesia remains in a state of purity.†

28. Oxalate.

Sp. 28. *Oxalate of magnesia.* This salt may be obtained by saturating oxalic acid with magnesia, and evaporating the solution. It is in the form of a white powder. It is tasteless, and not sensibly soluble in water; yet when oxalate of ammonia is mixed with sulphate of magnesia, no immediate precipitate falls. But if the solution be heated, and concentrated sufficiently, or if it be evaporated to dryness, and redissolved in water, in both cases the oxalate of magnesia separates in the

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* Ann. de Chim. xxvii. p. 21.

† Ibid. xxxiii. 55.

state of an insoluble powder. The constituents of this salt are as follows:

	[*]	[†]	[‡]	[§]
Acid	65	73·68	72·65	64·33
Magnesia	35	26·32	27·35	35·67
	100	100·00	100·00	100·00

29. Tartrate.

Sp. 29. *Tartrate of magnesia.* This salt is insoluble in water except there be an excess of acid present. It then affords by evaporation small crystals in the form of hexangular truncated prisms.[||] It has a more saline taste, and is more fusible than tartrate of lime.[**] Heat first melts and afterwards decomposes it.

Sp. 30. *Tartrate of potash and magnesia.* This triple salt, first examined by the Dijon academicians, may be formed by dissolving magnesia or its carbonate in tartar. The solution, according to them, yields by evaporation needle-form crystals; but, according to Thenard, this triple salt does not crystallize; and when evaporated, it deliquesces.[††]

31. Citrate.

Sp. 31. *Citrate of magnesia.* This salt may be formed by dissolving carbonate of magnesia in citric acid. This solution, though evaporated to a thick syrup, does not crystallize, but it gradually assumes the form of a white opaque soft mass, which rises in the vessel like a mushroom. According to Vauquelin, it is composed of

66·66	acid
33·34	magnesia
100·00[‡‡]	

If we consider it as a compound of 1 atom acid + 1 atom base, its constituents must be

Acid	74·68
Magnesia	25·32
	100·00

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[*] Bergman, Opusc. i. 262 and 387.

[†] By my analysis.

[‡] Berard, Ann. de Chim. 73, 284.

[§] Theoretical composition. The acid considered both by myself and Berard as pure contained water. Hence the reason why our results are inaccurate. Bergman comes much nearer the truth.

[||] Bergman, i. 388.

[**] Von Packen de Sale Essent. Acid Tartar.

[††] Ann. de Chim. xxxviii. 32.

[‡‡] Fourcroy, vii. 208.

Sp. 32. *Saclactate of magnesia.* A white powder insoluble in water.

Sp. 33. *Urate of magnesia.* A white tasteless powder similar in appearance to uric acid.

Sp. 34. *Malate of magnesia.* Permanent crystals soluble at 60° in 28 times their weight of water.[*]

35. Lactate.

Sp. 35. *Lactate of magnesia.* When the solution of this salt is evaporated to the consistence of a thin syrup and left in a warm place, it shoots into small granular crystals. When hastily evaporated to dryness it furnishes a gummy mass. Alcohol resolves it into two subspecies; neutral lactate which it dissolves, and sublactate which it leaves untouched.[†]

Sp. 36. *Gallate of magnesia.* When magnesia is boiled with the infusion of nutgalls, the liquid becomes almost limpid, and assumes the same green colour as similar mixtures. From the experiments of Davy, it appears, that in this case all the extract of tan is separated from the infusion, together with a portion of the gallic acid; and that the liquid holds in solution nothing but a combination of that acid and magnesia. But the acid is decomposed, and the green colour disappears, when we attempt to obtain the composition in a dry state.

◆

The composition of the salts of magnesia is easily determined by considering them as compounds of 1 atom magnesia and 1 atom of each of the acids. An atom of magnesia weighs 2·5, and the weight of an atom of each of the acids has been given in a preceding chapter of this volume.

Of the salts of magnesia the most useful are the carbonate and sulphate, both of which are very much employed in medicine.

SECT. XIII.

SALTS OF YTTRIA.

The greater number of the salts which yttria is capable of forming with acids still continue unknown.

General properties.

1. A considerable number of the salts of yttria are insoluble in water, and have not therefore been obtained in the state of crystals.

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[*] Donovan, Phil. Trans. 1815.

[†] Berzelius, Djurkemien, ii. 437.

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2. Yttria may be precipitated from its solutions in acids by phosphate of soda, carbonate of soda, oxalate of ammonia, and tartrate of potash.

3. It is precipitated likewise by ferrochyazate of potash.

4. Yttria bears a considerable resemblance to lime in the solubility of the salts which it forms. If we except sulphate of yttria, which is much more soluble than sulphate of lime, and which is easily recognized by its sweet taste. This difference enables us readily to distinguish yttria from lime.

1. Nitrate.

Sp. 1. *Nitrate of yttria.* This salt was first formed by Mr. Ekeberg: it has been more lately examined by Vauquelin. It may be prepared by dissolving yttria in nitric acid. The solution has a sweet astringent taste, and in most of its properties agrees with nitrate of glucina. Like it, this salt can scarcely be obtained in the state of crystals. If, during the evaporation, a heat somewhat too strong be applied, the salt becomes soft, and assumes the appearance of honey, and on cooling becomes hard and brittle like a stone. When exposed to the air, it very soon attracts moisture, and deliquesces. When sulphuric acid is poured into this solution, crystals of sulphate of yttria are instantly precipitated.*

2. Carbonate.

Sp. 2. *Carbonate of yttria.* This salt may be formed by precipitating yttria from its solution in acids by means of an alkaline carbonate. It is a white, tasteless, insoluble powder, composed of

18	acid
55	yttria
27	water
100 †	

According to Vauquelin, it loses 32 per cent. when calcined.‡ If we suppose it a compound of 1 atom acid + 1 atom yttria, its constituents will be

Acid	35·48
Base	64·52
	100·00

3. Phosphate.

Sp. 3. *Phosphate of yttria.* This salt has only been formed by Vauquelin. When the solution of phosphate of

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* Ann. de Chim. xxxvi. 156.

† Klaproth's Beitrage, iii. 67.

‡ Ann. du Mus. d'Hist. Nat. xv. 9.

soda is mixed with the sulphate, nitrate, or muriate of yttria, phosphate of yttria precipitates in gelatinous flakes.[*]

Sp. 4. *Sulphate of yttria.* This salt was first formed by Gadolin, and afterwards it was examined with more precision by Ekeberg,[†] Vauquelin,[‡] and Klaproth.[§]

Sulphuric acid dissolves yttria readily, and some caloric is evolved during the process. As the solution goes on, the sulphate crystallizes in small brilliant grains.

Properties.

These crystals are irregular, but most frequently, according to Ekeberg, they have the form of flat six-sided prisms terminated by four-sided summits. In my experiments I obtained long slender rhomboidal prisms. These crystals are not altered by exposure to the air. Their taste is astringent and sweetish, though not so much so as sulphate of glucina. Their colour is a light amethyst red; their specific gravity 2·791. They require at least 30 parts of water of the temperature of 60° to dissolve them. At a red heat they are partly decomposed.

Oxalic acid, ferrochyazate of potash, and the infusion of nutgalls, occasion a precipitate in the aqueous solution of this salt. It is decomposed by phosphate of soda.

Sulphate of glucina is readily distinguished from this salt by its being colourless, lighter, and more soluble in water.

Sp. 5. *Seleniate of yttria.* When an alkaline seleniate is dropt into a solution of yttria, a white precipitate falls in large flocks, which do not dissolve in an excess of selenic acid. When dry it has the appearance of a white powder. On exposure to heat it first parts with its water and then with its acid.[||]

Sp. 6. *Arseniate of yttria.* When yttria is dissolved in arsenic acid, and the solution boiled, arseniate of yttria precipitates in the state of a white powder.[**] Arseniate of potash precipitates yttria from acids.[††]

7. Chromate.

Sp. 7. *Chromate of yttria.* Chromic acid dissolves yttria cold in considerable quantity and with effervescence. The solution has an astringent and pungent taste, and, like most of the chromates, has an orange-red colour passing into yellow.

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[*] Ann. de Chim. xxxvi. 158.

[†] Crell's Annals, 1799, ii. 68.

[‡] Ann. de Chim. xxxvi. 156.

[§] Beitrage, iii. 67.

[||] Berzelius; Ann. de Chim. et de Phys. ix. 265.

[**] Ekeberg, Crell's Annals, 1799, ii. 70.

[††] Klaproth's Beitrage, iii. 76.

The solution is quite neutral. When evaporated, it forms dendrites consisting of prisms and cubes. It is very soluble in water.[*]

Sp. 8. *Acetate of yttria.* Yttria dissolves readily in acetic acid, and the solution yields by evaporation crystals of acetate of yttria. These crystals have most commonly the form of thick six-sided plates obliquely truncated. Their colour is amethyst red. They are not altered by exposure to the air.[†]

9. Succinate. Sp. 9. *Succinate of yttria.* Yttria is not precipitated from its solution in acids by the succinates, according to Ekeberg.[‡] This however must be understood with some limitation; for as the succinate of yttria is but sparingly soluble in water, it precipitates in crystals, if a concentrated solution of an alkaline succinate be mixed with a saturated solution of yttria in an acid. Thus, when the succinate of soda is dropped into concentrated muriate or acetate of yttria, small cubic crystals fall, which are succinate of yttria.[§]

10. Oxalate. Sp. 10. *Oxalate of yttria.* When oxalic acid, or the oxalate of ammonia, is dropped into a solution of yttria in acids, a white insoluble powder precipitates, which is the oxalate of yttria.[||] It is composed, according to the experiments of Vauquelin, of

Acid	57·5
Yttria	42·5
	100·0[**]

Sp. 11. *Tartrate of yttria.* Yttria is precipitated from its solution in acids by tartrate of potash; but an addition of water dissolves the precipitate.[††] Hence it follows that tartrate of yttria is soluble in water.

SECT. XIV.

SALTS OF GLUCINA.

The salts of glucina have been examined equally imperfectly with the salts of yttria.

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[*] John, Annals of Philosophy, iv. 426.

[†] Ekeberg, Crell's Annals, 1799, ii. 69; and Klaproth's Beitrage, iii. 70.

[‡] Ann. de Chim. xliii. 277.

[§] Klaproth's Beitrage, iii. 76.

[||] Klaproth's Beitrage, iii. 75.

[**] Ann. du Mus. d'Hist. Nat. xv. 9.

[††] Klaproth's Beitrage, iii. 75.

General properties.

1. The salts of glucina are much more soluble in water than those of yttria, and a smaller number of them seem susceptible of crystallizing.

2. The salts of glucina are not precipitated by oxalate of ammonia or tartrate of potash which sufficiently distinguishes them from salts of yttria.

3. Ferrochyazate of potash occasions a white precipitate when dropped into the solution of a salt of glucina.

4. Infusion of nut-galls occasions a yellow precipitate; which acquires a purplish tinge if any iron be present.

5. The sulphate of glucina does not crystallize, nor do crystals of alum form in it when sulphate of potash is mixed with the solution.

1. Nitrate. Sp. 1. *Nitrate of glucina.* This salt was first described by Vauquelin. It is prepared by saturating nitric acid with glucina. When this solution is evaporated by means of a low heat, the salt gradually assumes the form of a powder, but cannot be obtained in the state of crystals.

Its taste is sweet and astringent. It is exceedingly soluble in water; so much so indeed that it is very difficult to obtain it in a dry state. When evaporated, it becomes thick and glutinous like honey. When exposed to the air, it attracts moisture very rapidly. When heated it readily melts; and if the heat be increased, the acid escapes, and leaves the earth in a state of purity. When tincture of nut-galls is dropped into a solution of this salt, a yellowish-brown precipitate immediately appears. Nitrate of glucina may be readily distinguished from nitrate of alumina by this property.

Sp. 2. *Carbonate of glucina.* This salt has been examined only by Vauquelin. It may be prepared by precipitating glucina from its solution in acids by an alkaline carbonate, and washing the precipitate sufficiently with pure water. It is in the state of a white soft powder, which has a greasy feel. It has no taste, and is exceedingly light. It is insoluble in water, not altered by exposure to the air, easily decomposed, and its acid driven off by the application of heat. It loses half of its weight in a red heat.

3. Phosphate. Sp. 3. *Phosphate of glucina.* This salt has been examined only by Vauquelin. He obtained it by pouring phosphate of soda into the solution of glucina in sulphuric, nitric, or muriatic acid. The phosphate of glucina is precipitated in the state of a white powder. Properties. It does not crystallize. It is tasteless, insoluble in water, unless it contains an excess of acid

and not liable to be altered by exposure to the air. When heated strongly, it melts into a transparent glass.

4. Sulphate.

Sp. 4. *Sulphate of glucina.* This salt was first examined by Vauquelin, the discoverer of its base.

It is prepared by saturating sulphuric acid with glucina. The acid dissolves the earth readily, and the solution by evaporation yields small needle-form crystals, the figure of which has not been ascertained.

Properties.

It has a very sweet and somewhat astringent taste. It is soluble in water; the solution readily assumes the consistence of a syrup, but does not crystallize. When heated it undergoes the watery fusion, loses its water, and falls to powder. At a red heat it is decomposed completely, the acid is driven off, and the earth remains in a state of purity. The infusion of nut-galls, when dropped into the solution of this salt, occasions a yellowish white precipitate.

Subspecies.

Berzelius has shown that there are three subspecies of sulphate of glucina; 1. Neutral sulphate, forming a gummy-like mass, composed of

Sulphuric acid	100	or 1 atom
Glucina	64·1	1

The second, a bisulphate obtained by dissolving glucina in sulphuric acid and evaporating the solution, composed of

Acid	100	or 2 atoms
Glucina	32·15	1

The third, a subsesquisulphate composed of 2 atoms acid and 3 atoms glucina obtained by digesting carbonate of glucina in the solution of the second subspecies. It was composed of

Acid	100
Glucina	98·4[*]

If we suppose the constitution of these three salts to be as I have stated them, their composition will be as follows:

1. Neutral salt.

Acid	100
Glucina	65

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[*] Berzelius, attempt to establish a pure scientific system of Mineralogy. p. 134.

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2. Bisulphate.

Acid	100
Glucina	32·5

3. Subsequisulphate.

Acid	100
Glucina	97·5

Sp. 5. *Seleniate of glucina.* The neutral salt is a white insoluble powder. The biseleniate is soluble. When evaporated it gives a gummy looking mass. Heat decomposes both of these salts.*

Sp. 6. *Chromate of glucina.* Glucina thrown down by carbonate of potash is dissolved very slowly by concentrated chromic acid. The solution has a yellow colour, and does not seem capable of crystallizing.†

Sp. 7. *Chromo-sulphate of glucina.* When sulphate of glucina is poured into chromic acid the appearance of the solution is not altered; but when the liquid is evaporated there remains behind a triple salt in dendritical crystals in a state of efflorescence.‡

Sp. 8. *Acetate of glucina.* Acetate of glucina is sweet and astringent, has an excess of acid, and does not crystallize, but forms a gummy mass in thin transparent plates, soluble in water, and still acid.§

Sp. 9. *Succinate of glucina.* Ekeberg has announced, that glucina is precipitated from its solution in acids by the succinates. The succinate of glucina is of course insoluble, or nearly so.||

Sp. 10. *Oxalate of glucina.* As acetate of glucina is not precipitated by oxalate of ammonia, we may infer that the oxalate of glucina is soluble in water.

Such is the small number of these salts hitherto examined. Not one of them crystallizes except the chromo-sulphate, and its crystals are imperfect.

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* Berzelius, Ann. de Chim. et de Phys. ix. 265.

† John, Annals of Philosophy, iv. 425. ‡ Ibid.

§ Vauquelin, Ann. du Mus. d'Hist. Nat. xv. 9.

|| Ann. de Chim. xliii. 277.

SECT. XV.

SALTS OF ALUMINA.

General properties.

1. Most of the salts of alumina, are soluble in water, and few of them are capable of crystallizing.

2. They are distinguished by a sweet and astringent taste, in which respect they resemble the salts of yttria and glucina.

3. They are not precipitated by oxalate of ammonia nor tartaric acid, which sufficiently distinguishes them from salts of yttria.

4. They are not precipitated by ferrochyazate of potash, nor by tincture of nut-galls, in which respects they differ both from the salts of yttria and glucina.

5. Phosphate of ammonia, when dropped into a salt of alumina, occasions a white precipitate.

6. Hydriodate of potash occasions a white flocky precipitate in a solution of alumina, which speedily becomes yellow and continues permanent. This is not owing to the excess of acid which the salts of alumina usually contain, for the yellow colour does not disappear on the addition of carbonate of ammonia.

7. If sulphuric acid, and then sulphate of potash be added to a salt of alumina, and the mixture be set aside, octahedral crystals of alum speedily make their appearance in it.

1. Nitrate.

Sp. 1. *Nitrate of alumina.* Though this salt has been known to chemists for many years past, it has not hitherto been examined with precision. It is prepared by dissolving alumina in nitric acid, and evaporating the solution till the salt crystallizes. This salt always contains an excess of acid, and is therefore one of the few *supernitrates* with which we are acquainted.

It crystallizes with great difficulty in thin soft plates, which have but little brilliancy. This salt has an acid and astringent taste. Its specific gravity is 1·645.* It is exceedingly soluble in water, and when evaporated is converted into a glutinous mass of the consistence of honey. It often assumes on cooling the form of a jelly. When exposed to the air, it very soon attracts moisture and deliquesces. When heated, the acid is disengaged with great facility, and the earth remains behind in a state of purity.

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* Hassenfratz, Ann. de Chim. xxviii. 12.

2. Carbonate.

Sp. 2. *Carbonate of alumina.* The greater number of chemists have agreed in admitting the existence of this salt. Bergman could not form it artificially; but he allows its existence, because when alum is mixed with an alkaline carbonate, part of the alumina remains in solution till the carbonic acid be driven off.[*] Saussure has shown that water saturated with carbonic acid is capable of dissolving alumina; but this combination is destroyed by simple exposure to the air. Carbonate of alumina, then, cannot exist in a dry state. What had been considered formerly as a dry carbonate is a triple compound of alumina, carbonic acid, and the alkali employed in precipitating the alumina.[†] I find, however, that alumina thrown down by a carbonate effervesces when dissolved in acids.

Sp. 3. *Borate of alumina.* This salt may be formed by mixing together the solutions of borate of soda and sulphate of alumina. It is said to be scarcely soluble in water, and not to crystallize.

Sp. 4. *Silicate of alumina.* The salt may be obtained by mixing together silicate of potash and solution of alumina in potash. The silicate of alumina gradually forms a jelly, and may be separated by the filter.

Sp. 5. *Silicate of potash-and-alumina.* The well known mineral called *felspar* is a triple salt, composed of 1 atom silicate of potash, and 3 atoms silicate of alumina united together.

Sp. 6. *Silicate of soda-and-alumina.* The mineral called *sodalite* is a triple salt composed of 1 atom of silicate of soda, and 2 atoms of silicate of alumina.

7. Phosphate.

Sp. 7. *Phosphate of alumina.* This salt has been examined by Fourcroy only. It may be formed by saturating phosphoric acid with alumina. It is a tasteless powder, insoluble in water. Dissolved in phosphoric acid, it yields a gritty powder, and a gummy solution, which by heat is converted into a transparent glass.

8. Sulphate.

Sp. 8. *Sulphate of alumina.* This salt may be formed by dissolving alumina in sulphuric acid, evaporating the solution to dryness, dissolving it again in water, and evaporating it till it crystallizes. Little attention has hitherto been paid to this salt, which was never properly distinguished from alum till two memoirs, one by Vauquelin and another by Chaptal, on the nature of alum, made their appearance in the 22d volume of the Annales de Chimie.

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[*] Bergman, i. 32.

[†] Jour. de Phys. lii. 28.

Properties.

It crystallizes in thin plates, soft and pliant, and of a pearly lustre. Its taste is astringent. It is very soluble in water, and does not crystallize without difficulty. When heated it loses its water of crystallization, and falls to powder. A strong heat decomposes it completely by volatilizing the acid. It is not altered by exposure to the air.

Sp. 9. *Alum.* Of this salt there are no less than four subspecies, all of which are triple salts; two neutral, and two in the state of supersalts. These varieties may be distinguished by the following names:

Subspecies.

1. Sulphate of alumina-and-potash.
2. Sulphate of alumina-and-ammonia.
3. Supersulphate of alumina-and-potash.
4. Supersulphate of alumina-and-ammonia.

The two last of these varieties are usually confounded together under the name of *alum:* the two first have been called *alum saturated with its earth*, and sometimes *aluminated alum.* It will be proper to consider the two last varieties first, because they have been longest known, and are the most important.

Alum.

1. *The supersulphates.* The στυπτηρια of the Greeks, and the *alumen* of the Romans, was a native substance which appears to have been nearly related to *green vitriol*, or *sulphate of iron;* and which consequently was very different from what we at present denominate *alum.* From the researches of Professor Beckman, it appears that we owe the discovery of alum to the Asiatics; but at what period, or by what means, the discovery was made is altogether unknown. It continued to be imported from the east till the 15th century, when a number of alum works were established in Italy. In the 16th century it was manufactured in Germany and Spain; and during Queen Elizabeth's reign an alum work was established in England by Thomas Chalomer. The alum of commerce is usually obtained from native mixtures of pyrites and clay, or sulphuric acid and clay.

Bergman has published a very complete dissertation on the process usually followed.* The earth from which it is procured is usually called *alum slate*, because it is slaty. Its colour is blackish, because it contains some bitumen. In most cases it is necessary to burn it before it can be employed; this is done by means of a slow smothered fire. Some-

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* Opusc. i. 279.

times long exposure to the weather is sufficient to produce an efflorescence of alum on the surface. It is then lixiviated, and the water concentrated by evaporation, and mixed with putrid urine, or muriate of potash; crystals of alum and of sulphate of iron usually form together.

The composition of alum has been but lately understood with accuracy. It has been long known, indeed, that one of its ingredients is sulphuric acid;* and the experiments of Pott and Margraff proved incontestibly that alumina is another ingredient. But sulphuric acid and alumina are incapable of forming alum. Manufacturers knew that the addition of a quantity of potash or of ammonia, or of some substance containing these alkalies, is almost always necessary; and it was proved, that in every case in which such additions are unnecessary, the earth from which the alum is obtained contains already a quantity of potash. Various conjectures were made about the part which potash acts in this case; but Vauquelin† and Chaptal‡ appear to have been the first chemists that ascertained by decisive experiments that alum is a triple salt, composed of sulphuric acid, alumina, and potash or ammonia, united together.

Properties.

Alum crystallizes in regular octahedrons, consisting of two four-sided pyramids applied base to base. The sides are equilateral triangles. The form of its integrant particles, according to Haüy, is the regular tetrahedron. Its taste is sweetish and very astringent. It always reddens vegetable blues. Its specific gravity is 1·7109.§ At the temperature of 60° it is soluble in from 15 to 20 parts of water, and in $\frac{3}{4}$ths of its weight of boiling water. When exposed to the air it effloresces slightly. When exposed to a gentle heat it undergoes the watery fusion. A strong heat causes it to swell and foam, and to lose about 44 per cent. of its weight, consisting chiefly of water of crystallization.‖ What remains is called *calcined* or *burnt alum*, and is sometimes used as a corrosive. By a violent heat, the greater part of the acid may be driven off. In that case, as was first observed by Milner,

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* Some chemists have thought proper to call the sulphuric acid, obtained by distilling alum, *spirit of alum*.

† Ann. de Chim. xxii. 258.

‡ Ibid. 280.

§ Hassenfratz, Ann. de Chim. xxviii. 12. Wallerius found it 1·710 (Chemistry, p. 266); and Dr. Watson, 1·757 (Essays, v. 67); Fahrenheit, 1·738. (Phil. Trans. liii. 114.)

‖ Bergman. i. 287.

a portion of the acid is decomposed into sulphurous acid and oxygen gas.

Though the properties of alum are in all cases pretty nearly the same, it has been demonstrated by Vauquelin that three varieties of it occur in commerce. The first is *supersulphate of alumina-and-potash;* the second, *supersulphate of alumina-and-ammonia;* the third is a mixture or combination of these two, and contains both potash and ammonia. It is the most common of all; doubtless, because the alum makers use both urine and muriate of potash to crystallize their alum. Vauquelin, Thenard, and Roard have lately analyzed a number of specimens of alum manufactured in different countries. The result was that they all contain very nearly the same proportion of ingredients. The mean of all the good analyses hitherto made is as follows:

Constituents.

	*	†	‡
Acid	30·52	26·04	34·23
Alumina	10·50	12·53	10·86
Potash	10·40	10·02	9·81
Water	48·58	51·41	45
	100·00	100·00	99·9

The analysis of Berzelius is equivalent to

Sulphate of alumina	36·85
Sulphate of potash	18·15
Water	45·00
	100·00

If we consider it as a compound of 3 atoms sulphate of alumina, 1 atom sulphate of potash, and 23 atoms of water, its constitution will be as follows:

Sulphate of alumina	36·70
Sulphate of potash	18·88
Water	44·42
	100·00

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* Vauquelin, Ann. de Chim. l. 167. Small quantities of ammonia also occurred in several.

† Thenard and Roard, Ann. de Chim. lix. 72. The acid was estimated by means of sulphate of barytes, which they considered as containing only 26 per cent. of sulphuric acid; whereas it contains 34 per cent.; of course the proportion of that acid in the table is too small.

‡ Berzelius, Ann. de Chim. lxxxii. 258.

Proportions which come sufficiently near the analysis to leave no doubt respecting their accuracy.

From the analyses and experiments of Thenard and Roard, it appears that alum usually contains a little sulphate of iron. Its good qualities as a mordant in dyeing depend upon the proportion of that salt present. The more free it is from it the better. The purest alum examined contained about $\frac{1}{2000}$th part of its weight of sulphate of iron, the impurest about $\frac{1}{1000}$. When freed from sulphate of iron every species of alum tried acts exactly in the same manner as a mordant.[*]

Cubic alum.

When an unusual quantity of potash is added to alum liquor, the salt loses its usual form and crystallizes in cubes. This constitutes a fourth subspecies of alum, usually distinguished by the name of *cubic alum*. It contains an excess of alkali.

When the potash is still further increased, Chaptal has observed that the salt loses the property of crystallizing altogether, and falls down in flakes. This constitutes a fifth subspecies of alum, consisting of sulphate of potash combined with a small proportion of alumina.

Neutral compounds.

2. *The sulphates.* All the varieties of alum are capable of combining with an additional dose of alumina, and forming perfectly neutral compounds; all possessed of nearly the same properties, and therefore confounded together as one salt.

Properties.

It may be prepared by boiling a solution of alum with pure alumina; the compound, as it forms, gradually precipitates in the form of a white powder. It was formerly denominated *alum saturated with its earth.* This salt does not crystallize, but has always the form of a tasteless powder. It is insoluble in water, and not altered by exposure to the air. Heat has no effect upon it unless it be very violent; and in that case part of the acid is disengaged. Sulphuric acid converts it into alum. It is less easily decomposed by other bodies than alum. Several of the acids dissolve slowly its last dose of alumina, and convert it into alum. This salt has not hitherto been applied to any use. Alum is capable also, as Chaptal informs us, of combining with several other bases, and of forming many triple salts, which have never yet been examined with attention.[†]

Homberg's pyrophorus.

If three parts of alum and one of flour or sugar be melted together in an iron ladle, and the mixture dried till it becomes

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[*] Ann. de Chim. lix. 58.

[†] Ibid. xxii. 293.

blackish and ceases to swell; if it be then pounded small, put into a glass phial, and placed in a sand-bath till a blue flame issues from the mouth of the phial, and after burning for a minute or two be allowed to cool,* a substance is obtained known by the name of *Homberg's pyrophorus,* which has the property of catching fire whenever it is exposed to the open air, especially if the air be moist.

This substance was accidentlly discovered by Homberg about the beginning of the 18th century, while he was engaged in his experiments on the human fæces. He had distilled a mixture of human fæces and alum till he could obtain nothing more from it by means of heat; and four or five days after, while he was taking the residuum out of the retort, he was surprised to see it take fire spontaneously. Soon after. Lemery, the younger, discovered that honey, sugar, flour, or almost any animal or vegetable matter, could be substituted for human fæces; and afterwards Mr. Lejoy de Suvigny showed that several other salts containing sulphuric acid may be substituted for alum.† Scheele proved that alum deprived of potash is incapable of forming pyrophorus, and that sulphate of potash may be substituted for alum.‡ And Mr. Proust has shown that a number of neutral salts, composed of vegetable acids and earths, when distilled by a strong fire in a retort, leaves a residuum which takes fire spontaneously on exposure to the air. From the observations of Davy and Coxe, there can be no doubt that this pyrophorus owes its properties to a little potassium which it contains, and which is reduced during the process for making the substance.

Sp. 10. *Sulphate of lithia and alumina.* Arvedson affirms that when sulphate of lithia is added to sulphate of alumina, a double salt is gradually deposited in octahedral or dodecahedral crystals.§ But Gmelin attempted three different times to form this salt without success.‖ It is probable therefore that Arvedson's sulphate of alumina had not been quite free from alum.

Sp. 11. *Sulphite of alumina.* This salt was first formed by Berthollet; it has been described by Fourcroy and Vauquelin.

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* Care must be taken not to keep it too long exposed to the heat.

† See Macquer's Dictionary.

‡ Scheele on Fire and on Pyrophorus.

§ Ann. de Chim. et de Phys. x. 93.

‖ Gilbert's Annalen, lxii. 418.

When formed by the usual process it remains in the state of a white powder, and does not crystallize though dissolved in an excess of acid.

It is white and soft, and has an earthy and sulphureous taste. It is insoluble in water. When exposed to the air, it is gradually converted into sulphate. Its solution in sulphurous acid undergoes this change much more rapidly. When heated, its acid disengages, and the alumina remains behind, mixed however with a small proportion of sulphate of alumina.

Sp. 12. *Hyposulphite of alumina.* Mr. Herschell did not succeed in obtaining this salt. When oxalate of alumina was dropped into hyposulphite of lime no precipitate fell. He assures us that oxalate of alumina occasions no precipitate in muriate or nitrate of lime, any more than in hyposulphite.*

Sp. 13. *Seleniate of alumina.* The neutral salt is obtained by precipitating muriate of alumina by biseleniate of ammonia. It is a white powder insoluble in water. When heated, it allows first its water, and then its acid to escape.

Biseleniate is obtained by dissolving the seleniate or hydrate of alumina in selenic acid. It has an astringent taste, and yields by evaporation a transparent matter similar to gum.†

Sp. 14. *Arseniate of alumina.* Arsenic acid readily dissolves newly precipitated alumina. When the solution is evaporated, it gives a thick mass insoluble in water. This salt may be formed by mixing the alkaline arseniates with sulphate, nitrate, muriate, or acetate of alumina.‡

Sp. 15. *Tungstate of alumina.* An insoluble white powder.

16. Acetate. Sp. 16. *Acetate of alumina.* This salt can only be formed by digesting acetic acid on alumina recently precipitated. By evaporation needle-shaped crystals are obtained, which are very deliquescent. This salt has an astringent taste. Its specific gravity is 1·245.§ Gay-Lussac has observed that when the solution of acetate of alumina is heated, one half of the alumina precipitates, but is taken up again when the solution cools.|| The constituents of acetate of alumina are as follows:

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* Edin. Phil. Jour. i. 21.

† Berzelius, Ann. de Chim. et de Phys. x. 265.

‡ Scheele, i. p. 160.

§ Hassenfratz, Ann. de Chim. xxviii. 12.

|| Ann. de Chim. lxxiv. 193.

	*	†	‡
Acid	73·81	92·06	85·71
Base	26·19	7·94	14·29
	100·00	100·00	100·00

Sp. 17. *Benzoate of alumina.* This salt forms dendritical crystals. It has a sharp bitter taste, is soluble in water, and deliquesces when exposed to the air.

Sp. 18. *Succinate of alumina.* This salt, according to Wenzel, crystallizes in prisms, and is easily decomposed by heat.§

19. Camphorate.

Sp. 19. *Camphorate of alumina.* To prepare this salt, alumina, precipitated by means of ammonia and well washed, is to be mixed with water, and crystals of camphoric acid added. The mixture is then to be heated, filtered, and concentrated by evaporation. This salt is a white powder, of an acid bitterish taste, leaving on the tongue, like most of the aluminous salts, a sensation of astringency. Water at the temperature of 60° dissolves about $\frac{1}{200}$th part of its weight of this salt. Boiling water dissolves it in considerable quantities; but it precipitates again as the solution cools. Alcohol, while cold, dissolves it very sparingly; but when hot it dissolves a considerable quantity of it, which precipitates also as the solution cools. This salt undergoes very little alteration in the air; but it rather parts with than attracts moisture. Heat volatilizes the acid; and when the salt is thrown on burning coals, it burns with a blue flame.||

20. Suberate.

Sp. 20. *Suberate of alumina.* This salt does not crystallize. When its solution is evaporated by a moderate heat in a wide vessel, the salt obtained is of a yellow colour, transparent, having a styptic taste, and leaving an impression of bitterness on the tongue. When too much heat is employed, it melts and blackens. It reddens the tincture of turnsole, and attracts moisture from the air. Before the blow-pipe it swells up, the acid is volatilized and decomposed, and nothing remains but the alumina.**

21. Oxalate.

Sp. 21. *Oxalate of alumina.* Oxalic acid readily dissolves alumina, and forms a salt which is uncrystallizable, but fur-

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* Richter, Statique Chimique, i. 136.

† Wenzel, p. 157.

‡ Theoretical composition, supposing the salt composed of 2 atoms acid + 1 atom alumina.

§ Verwandt, p. 243.

|| Ann. de Chim. xxvii. 34.

** Ibid. xxiii. 55.

nishes on evaporation a yellowish pellucid mass. It is sparingly soluble in alcohol. It has a sweet astringent taste It is composed of

44 alumina
56 acid and water

100

When exposed to the air it deliquesces; and if it has been previously well dried, its weight is increased by $\frac{2}{3}$ds. It reddens turnsole.[*]

Alumina.

Sp. 22. *Mellate of alumina.* When mellitic acid is dropped into sulphate of alumina it throws down an abundant precipitate in the form of a white flaky powder.[†]

Sp. 23. *Tartrate of alumina.* This salt does not crystallize, but forms by evaporation a clear transparent gummy mass. Its taste is astringent. It is soluble in water. It does not deliquesce in the air.[‡]

Sp. 24. *Tartrate of potash-and-alumina.* This triple salt is formed by saturating tartar with alumina. It bears a very striking resemblance to the last described salt. Thenard has observed, that no precipitate is produced in this salt, either by the addition of alkalies or their carbonates.[§]

Sp. 25. *Saclactate of alumina.* A white powder insoluble in water.

Sp. 26. *Urate of alumina.* A white powder, scarcely distinguishable by its aspect from uric acid.

27. Malate.

Sp. 27. *Malate of alumina.* This salt is almost insoluble in water.[||] Of course it precipitates when malic acid is dropped into a solution containing alumina. Mr. Chenevix has proposed this acid to separate alumina from magnesia; which earths, as is well known, have a strong affinity for each other.[||]

Sp. 28. *Lactate of alumina.* A salt not altered by exposure to the air, and having the appearance of gum.[**]

Supergallate of alumina.

Sp. 29. *Gallate of alumina.* When a small portion of alumina is mixed with the infusion of nut-galls, it separates the whole of the tan and extract, and leaves the liquid limpid and of a very pale yellowish green colour. This liquid, by spontaneous evaporation, yields small transparent prismatic crystals,

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[*] Bergman, ii. 387.

[†] Vauquelin, Ann. de Chim. xxxvi. 210.

[‡] Von Packen.

[§] Ann. de Chim. xxxviii. 33.

[||] Ann. de Chim. xxviii. 921.

[**] Braconnot, Ann. de Chim. lxxxvi. 88.

which, according to Davy, are supergallate of alumina. They afford the only instance of a gallate capable of existing in the state of crystals. The quantity of alumina is very small; too small to disguise the properties of the acid.

Such are the properties of the salts of alumina, as far as they have been hitherto examined. Their composition is easily determined by considering them as composed of 1 atom of alumina united to 1 atom of each of the acids. An atom of alumina weighs 2·125, and the weight of an atom of each of the acids has been given in a preceding chapter of this volume.

Several of the salts of alumina, as alum and the acetate, are very much employed by dyers and calico-printers as a mordant to fix the different colours upon cloth. Alum is likewise employed in the preparation of leather, and for a great variety of other purposes exceedingly important in various manufactures.

SECT. XVI.

SALTS OF ZIRCONIA.

Zirconia dissolves in acids only when newly precipitated from its solutions and still moist. If it be dried, and especially if it be exposed to a red heat, it is acted on by acids with great difficulty.

General properties.

2. The alkalies, the alkaline earths, and the earths proper, separate zirconia from all its combinations with acids.

3. The greater number of the salts of zirconia are insoluble in water. This is the case with the sulphate, sulphite, phosphate, fluate, borate, carbonate, seleniate, oxalate, tartrate, citrate, saclactate, and gallate. The muriate, nitrate, acetate, benzoate, and malate, are soluble in water.

4. The salts of zirconia have an astringent taste, harsh, and disagreeable, similar to some of the metalline salts.

5. When sulphuric acid is dropped into a salt of zirconia, a white precipitate falls.

6. When carbonate of ammonia is dropped into a salt of zirconia, a white precipitate appears, which is re-dissolved if an additional portion of the carbonate of ammonia be added.

7. Oxalate of ammonia and tartrate of potash occasion a white precipitate when dropped into a salt of zirconia.

8. The infusion of nut-galls, when dropped into a solution of zirconia, occasions a white precipitate. The hydrosulphuret of potash occasions no precipitate, if the solution be free from iron.

1. Nitrate. Sp. 1. *Nitrate of zirconia.* This salt was first formed by Klaproth. Vauquelin has given us a detailed description of it. It may be easily formed by pouring nitric acid on newly precipitated zirconia.

Properties. It always contains an excess of acid. By evaporating, a yellowish transparent matter is obtained, exceedingly tenacious and viscid, and which dries with difficulty. It has an astringent taste, and leaves on the tongue a viscid matter, owing to its being decomposed by the saliva. It is only very sparingly soluble in water; the greatest part remains under the form of gelatinous and transparent flakes. Like all the other salts into which zirconia enters, it is decomposed by heat. It is decomposed also by sulphuric acid, which occasions a white precipitate soluble in excess of acid; by carbonate of ammonia, which produces a precipitate soluble by adding more carbonate; and by an infusion of nut-galls in alcohol, which produces a white precipitate soluble in an excess of the infusion, unless the zirconia contains iron; in which case the precipitate is a greyish blue, and part of it remains insoluble, giving the liquor a blue colour. This liquor, mixed with carbonate of ammonia, produces a matter which appears purple by transmitted light, but violet by reflected light. Gallic acid also precipitates nitrate of zirconia of a greyish-blue, but the colour is not so fine. Most of the other vegetable acids decompose this salt, and form combinations insoluble in water.*

Sp. 2. *Carbonate of zirconia.* This salt was formed by Vauquelin by precipitating zirconia from its solution in acids by alkaline carbonates. It is a tasteless white powder, composed of

44·5	acid and water
55·5	zirconia
100·0	

When heated the carbonic acid is driven off. This salt is soluble in the three alkaline carbonates, and seems to form with them triple salts.

Sp. 3. *Borate of zirconia.* A white insoluble powder.

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* Vauquelin, Ann. de Chim xxii. 199.

Sp. 4. *Phosphate of zirconia.* A white insoluble powder.

5. Sulphate.

Sp. 5. *Sulphate of zirconia.* This salt was first formed by Klaproth, but Vauquelin has described it with more precision. It is prepared by dissolving zirconia in sulphuric acid, and evaporating the solution to dryness.

Properties.

It is usually in the form of a white powder. It may, however, be obtained in small needle-form crystals. It has no taste, and is insoluble in water. It is not altered by exposure to the air. It is very easily decomposed by heat: the acid readily flies off, and leaves the earth in a state of purity. This decomposition may be accomplished even by boiling in water; the earth precipitates, and the acid remains in solution. Klaproth informs us, that with excess of acid sulphate of zirconia forms transparent stelliform crystals, soluble in water, and having an astringent taste.*

Sp. 6. *Sulphite of zirconia.* A white insoluble powder.

Sp. 7. *Seleniate of zirconia.* A white powder insoluble in water and in selenic acid. It is decomposed by heat.†

Sp. 8. *Acetate of zirconia.* This salt may be formed by pouring acetic acid on newly precipitated zirconia. It has an astringent taste. It does not crystallize; but when evaporated to dryness, it forms a powder, which does not attract moisture from the air as acetate of alumina does.‡ It is very soluble in water and in alcohol. It is not so easily decomposed by heat as nitrate of zirconia, probably because it does not adhere so strongly to water.§

Sp. 9. *Benzoate of zirconia.* This salt is soluble in water, but its properties have not been investigated.

Sp. 10. *Oxalate of zirconia.* A white insoluble powder.

Sp. 11. *Tartrate of zirconia.* A white insoluble powder.

Sp. 12. *Citrate of zirconia.* A white insoluble powder.

Sp. 13. *Saclactate of zirconia.* A white insoluble powder.

Sp. 14. *Malate of zirconia.* This salt is soluble in water, but its properties have not been examined.

Sp. 15. *Gallate of zirconia.* A white insoluble powder.

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* Jour. de Phys. xxxvi. 187.

† Berzelius, Ann. de Chim. et de Phys. x. 265.

‡ Klaproth, Jour. de Phys. xxxvi. 188.

§ Vauquelin, Ann. de Chim. xxii. 206

SECT. XVII.

SALTS OF IRON.

Book II. Division II.

The compounds which the acids form with the oxides of iron were formerly distinguished in chemistry by the epithet *martial,* because Mars was the title given by the alchymists to iron. The most important of these salts have been long known. Few metals attract oxygen and combine with acids with more facility than iron; many of its salts, therefore, are found ready formed, or at least are often formed during the multiplicity of operations to which this very useful metal is exposed. Some of these salts have been long of great importance in manufactures. They form the basis of writing ink and of the black dye, and are employed also to communicate several other colours to cloth.

Iron is capable of combining with two doses of oxygen, and several of the acids unite with each of its oxides. There are, therefore, two sets of salts which have iron for their bases; one set containing the black oxide, the other the red. The last of these sets was scarcely attended to by chemists till Mr. Proust published his Researches on Prussian Blue in 1797; in which he described the properties of the salt composed of the red oxide of iron and sulphuric acid; which, according to the rule formerly laid down, I shall call *persulphate of iron.* Since that time Davy has ascertained the existence of several more of these salts.

The salts of iron may be distinguished by the following properties:

Characters.

1. The greater number are soluble in water; and in general the solution has a greenish or yellowish-red colour, and an astringent taste.

2. Ferrochyazate of potash occasions in these solutions a precipitate of a deep blue, or at least which acquires that colour on exposure to the atmosphere.

3. Hydrosulphuret of potash occasions a black precipitate.

4. Sulphuretted hydrogen renders the solution nearly colourless, but occasions no precipitate.*

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* From this rule the oxygenized salts of iron must be excepted. In them, sulphuretted hydrogen occasions a precipitate. This precipitate is sulphur, thrown down by the decomposition of the sulphuretted hydrogen; at the same time the salt loses a portion of its oxygen. This gas likewise precipitates iron from its solution, in some of the weaker vegetable acids.

5. Gallic acid, or the infusion of nut-galls, occasions a black or purple precipitate, at least if the solution has been for some time exposed to the air.

6. Phosphate of soda, when dropped into a salt of iron, occasions a white precipitate.

7. Benzoate of ammonia precipitates the persalts of iron of a yellow colour.

8. Succinate of ammonia, dropped into solutions containing peroxide of iron occasions a flesh-coloured precipitate, and throws down all the iron. But this effect is not produced when the solution contains only protoxide of iron.

1. Nitrate.

Sp. 1. *Nitrate of iron.* Nitric acid, when as strongly concentrated as possible, does not act rapidly on iron; but when the acid is of a moderate strength, the action is very violent, a prodigious torrent of gas is extricated, which Dr. Priestley found to be a mixture of protoxide and deutoxide of azote. During this action the iron is oxidized to a maximum, and a red powder precipitates, consisting probably of pernitrate with excess of base. These phenomena have been long known; but it was not till after Mr. Proust's Researches on the Prussiates of Iron that the existence of two salts consisting of this acid, combined with each of the oxides of iron, was well understood by chemists. It is the pernitrate of iron which is obtained by the usual process. Mr. Proust merely announced the existence of the simple nitrate, but it has since been examined by Davy.

Formation.

1. *Protonitrate of iron.* When nitric acid of the specific gravity 1·16 is poured upon iron, it acts upon the metal but slowly, no gas being given out for some time. The solution becomes of a dark olive-brown in consequence of the nitrous gas which it holds in solution; but when exposed to the air, it becomes pale, because that gas combines with oxygen and is converted into nitric acid. When alkalies are poured into it, a pale green precipitate falls, consisting of iron oxidized to a minimum. This solution absorbs nitrous gas. It cannot be concentrated, nor even heated, without being converted into pernitrate.[*]

2. *Pernitrate of iron.* This is the salt obtained when iron is treated with strong nitric acid, or when the nitrate is heated or left exposed to the air. The solution is of a brown colour,

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[*] Davy's Researches, p. 187.

Properties.

and does not yield crystals. When evaporated, it lets fall a red powder, not afterwards soluble in nitric acid; and sometimes when concentrated assumes the form of a jelly. When strongly heated, the acid is disengaged, and the oxide remains in the form of a fine red powder. Hence solution in nitric acid, evaporating to dryness, and digesting the residuum in water, is the method recommended by Bergman, and formerly practised by chemists, to separate iron from earths. The iron and earths are first dissolved together in nitric acid; by the evaporation to dryness, and a strong heat, the nitrate of iron is decomposed, while the earthy nitrates remain unaltered. They are of course dissolved by the water, but the red oxide of iron is left untouched.

Crystals.

Vauquelin has discovered a method of obtaining the pernitrate of iron in crystals. When concentrated nitric acid is kept for some months in contact with the black oxide of iron, solution slowly takes place, and crystals nearly colourless are formed, which have the figure of rectangular four-sided prisms, terminated by dihedral ridges. These crystals have an acrid and inky taste, and are very deliquescent. Their solution in water has a red colour, and the alkalies precipitate from it red oxide of iron.*

2. Carbonate.

Sp. 2. *Carbonate of iron.* Liquid carbonic acid, when kept in contact with iron, attacks it slowly, and dissolves a sufficient quantity of it to acquire a sensibly chalybeate taste. When exposed to the air, the iron is gradually precipitated in the state of oxide;† and by boiling it is deposited in the form of a yellow ochre, still retaining a portion of acid. This carbonate often exists native in mineral waters. It may be obtained also by precipitating the sulphate of iron by means of an alkaline carbonate. In that case it is always in the form of a green mass, or hydrate, which gradually becomes black if the contact of air be excluded.

The carbonate of iron has been found native crystallized in rhombs at Eulenloh in Bareuth, a mineral lately described and analyzed by Bucholz. It is somewhat transparent, has a greenish-yellow colour, is brittle, easily pounded, and of the specific gravity 3·333. It dissolves slowly in acids. Its constituents, as ascertained by Bucholz, are

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* Fourcroy, vi. 205.

† Bergman, i. 33.

36·0	acid
59·5	protoxide
2·0	water
97·5	

The constituents ought to be

Carbonic acid	37·93
Protoxide of iron	62·07
	100·00

The water was, doubtless, only mechanically mixed. This mineral has the curious property of becoming a permanent magnet when it is heated red-hot.*

Rust.

Rust may be considered as a carbonate of iron; for it consists of the oxide of that metal combined with carbonic acid. Hence it dissolves in acids with effervescence, and when heated gives out carbonic acid gas: the residuum in that case is black oxide of iron.† Its brown colour seems to be owing to the presence of water. There is likewise a subcarbonate of iron, which, from the experiments of Bergman, seems to be composed of about

24	acid
76	oxide
100‡	

Stahl's tincture of Mars.

The liquid known by the name of Stahl's tincture of Mars, because it was discovered by that illustrious chemist, has not been examined by modern chemists; but it appears to be a triple, or rather quadruple saline compound. It is formed by pouring a solution of pernitrate of iron into liquid carbonate of potash: a red powder first precipitates, which is redissolved by agitating the mixture. The liquid of course is a *pernitro-carbonate of potash and iron.* But the combination is not permanent; for the liquid soon deposites a red powder.

3. Borate.

Sp. 3. *Borate of iron.* Boracic acid acts very feebly upon iron: but borate of iron may be obtained very readily by pouring liquid borate of soda into a solution of sulphate of iron. A pale yellow powder immediately precipitates, which is the

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* Bucholz, Gehlen's Jour. i. 231.

† Fourcroy, vi. 215.

‡ Bergman, ii. 392.

salt required. This salt is insoluble in water. Before the blow-pipe it melts readily into a globule of glass.*

4. Phosphate.

Sp. 4. *Phosphate of iron.* Phosphoric acid has but little action upon iron. However, if that metal remain exposed to the contact of phosphoric acid, or even to the solutions of salts which contain that acid, it is gradually oxidized, and converted into phosphate of iron. The properties of phosphated iron have not been examined with attention. Scheele has shown that the acid combines with both oxides, and forms of course both a *phosphate* and *perphosphate* of iron. Fourcroy and Vauquelin have ascertained that there are two varieties of this last salt; one which had been already described by Bergman, Meyer, Klaproth, and Scheele, and another with excess of base, and consequently a *subperphosphate*, which these philosophers first observed.

Varieties.

1. *Phosphate of iron.* When sulphate of iron dissolved in water is mixed with a solution of phosphate of potash, a blue powder precipitates, which is phosphate of iron. This powder is insoluble in water, and does not lose its colour when exposed to the air.† This salt is found native, and constitutes the colouring matter of a blue mineral called *native prussian blue*, found in bogs, and first analyzed by Klaproth. *Native prussian blue*, as it is called, when dry out of the earth, is at first often colourless; but when exposed to the air, it becomes blue. The cause of this change has not been ascertained.

This salt has been lately found native in small prismatic crystals. Specimens of it have been brought from Brazil and the Isle of France. Its colour is a light blue; it is partly transparent and partly opaque. Before the blow-pipe it runs into a metalline globule. When heated, it assumes the red colour of peroxide of iron. It dissolves readily in nitric acid. Its specific gravity is 2·6. By the analysis of Laugier, as confirmed by Fourcroy and Vauquelin, it is composed of

21	acid
45	protoxide
34	water
100‡	

I have examined phosphate of iron made artificially by mix-

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* Scheele, Crell's Annals, i. 114. Eng. Trans.

† Ibid. i. 115. Eng. Trans.

‡ Ann. de Chim. l. 214.

ing together solutions of sulphate of iron and phosphate of soda, and found it composed of equal weights of acid and base, or of 1 atom acid + 1 atom protoxide.

2. *Perphosphate of iron.* This salt may be readily procured by mixing together the solutions of permuriate of iron and phosphate of potash or soda. A white powder immediately falls, which is perphosphate of iron.

This salt, like almost all the phosphates, is soluble in acids, but precipitated undecomposed by ammonia. It is almost insoluble in water, as it requires more than 1500 parts of that liquid to dissolve 1 part of perphosphate. When heated violently, it melts into an ash-coloured globule.* When mixed with charcoal, and heated to redness, it is converted into phosphuret of iron.

3. *Subperphosphate of iron.* When the perphosphate of iron is treated with the pure fixed alkalies, a red, or rather brownish-red, powder is separated, while the alkali combines with phosphoric acid. This powder was examined by Fourcroy and Vauquelin, and found by them still to contain a portion of acid. It is therefore merely perphosphate with excess of base. This salt is scarcely soluble in acids or in water.

5. Sulphate.

Sp. 5. *Sulphate of iron.* Concentrated sulphuric acid acts but very slowly upon iron, unless it be assisted by heat. In that case the metal is oxidized, and sulphurous acid gas exhaled. But diluted sulphuric acid dissolves iron with great rapidity, and abundance of hydrogen gas is emitted. In this case the water is decomposed; its oxygen combines with the iron, while its hydrogen is emitted. The solution has a green colour, and when evaporated immediately, yields crystals of *sulphate* of iron; but if allowed to remain exposed to the atmosphere, it gradually attracts more oxygen, and is converted into *persulphate*, unless it contains an excess of acid; which retards, and, when sufficiently abundant, prevents the change.

History.

1. *Sulphate of iron.* This salt was known to the ancients, and is mentioned by Pliny under the names of *misy*, *sory*, and *calchantum*.† In commerce it is usually denominated *green vitriol* or *copperas*. It is not prepared by dissolving iron in sulphuric acid, but by moistening the pyrites which are found native in abundance, and exposing them to the open air. They are slowly covered with a crust of sulphate of iron,

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* Bergman, iii. 118.

† Lib xxxiv. c. 12.

which is dissolved in water, and afterwards obtained in crystals by evaporation. Sometimes the salt is found ready formed, either in a state of solution in water or mixed with decayed pyrites. In some cases it is found necessary to roast the pyrites before they can be made to undergo spontaneous decomposition. This is most probably owing to the compact state of the pyrites in these cases, and the absence of all uncombined iron. Pyrites is in fact a bisulphuret of iron. The roasting reduces it to the state of sulphuret, which decomposes very readily. The solution always contains an excess of acid. Hence it is necessary, in order to obtain the salt in crystals, to throw into it a quantity of old iron.

Properties.

Sulphate of iron has a fine green colour. Its crystals are transparent rhomboidal prisms, the faces of which are rhombs with angles of 79° 50′ and 100° 10′, inclined to each other at angles of 98° 37′ and 81° 23′.* It has a very strong styptic taste, and always reddens vegetable blues. Its specific gravity is 1·8399.† It is soluble in about two parts of cold water, and in $\frac{3}{4}$ths of its weight of boiling water. It is insoluble in alcohol. When exposed to the air, its surface gradually becomes opaque, and is covered with a yellow powder; because it absorbs oxygen, and is partially converted into persulphate. This change takes place much more rapidly and completely if the salt be moistened with water. The cause of these phenomena was first explained by Scheele.

When heated it melts, gradually loses its water of crystallization, and by a strong heat sulphuric acid is driven off, and there remains behind a red powder, formerly known by the name of *colcothar of vitriol*, which is either a mixture of red oxide of iron and persulphate, or pure oxide, according to the heat applied. When this salt is distilled, there comes over first water slightly acidulated with sulphuric acid, and afterwards a very strong fuming acid, formerly known by the name of *glacial oil of vitriol*. The residuum is the same mixture of oxide and persulphate which is obtained by calcination in the open air. This decomposition, which sulphate of iron undergoes when heated, enables it in many cases, in a high tempe-

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* Haüy, Jour. de Min. An. v. 542.

† Hassenfratz, Ann. de Chim. xxviii. 12. According to Wallerius, the specific gravity is 1·880 (Chemiæ, p. 266); according to Dr. Watson, 1·812 (Essays, v. 67); when calcined to whiteness, its specific gravity becomes 2·636 (Watson, ibid.) I found it 1·980.

rature to act nearly the same part as sulphuric acid. Hence it is often employed by manufacturers to disengage the weaker acids from their bases.

This salt, according to the best analyses hitherto made, is composed of the following proportions:

Composition.

	*	†	‡	§
Acid	26	26·7	28·9	28·77
Base	28	28·3	25·7	25·89
Water	46	45·0	45·4	45·34
	100	100·0	100·0	100·00

When the crystals of sulphate of iron are moderately heated, they assume at first a white colour; the same change of colour is observed when the salt, in the state of powder, is infused in alcohol. Hence we see the separation of the water changes the colour from green to white; and if water be now poured on the white powder, it becomes again green.

The sulphate of iron is decomposed by the alkaline phosphates and borates, and by the greater number of those salts whose base forms an insoluble compound with the sulphuric acid, as nitrate of silver, of lead, of barytes, &c.

2. *Persulphate.* Of this salt there are three subspecies, namely, *neutral persulphate*, *tripersulphate*, and *subbipersulphate.*

The neutral persulphate is formed when concentrated sulphuric acid is digested on peroxide of iron in a flask. A white compound is obtained. It cannot be examined. But there cannot be a doubt, that if the acid and oxide be employed in the proper proportions the compound would be neutral. When water is poured upon it a milky liquid is formed, which is gradually separated into two salts, a subsalt falls to the bottom in the state of a red powder, and a supersalt, which remains in solution in the water giving it a red colour. I conceive the original white matter to be a persulphated hydrate. The reason why the neutral persulphate cannot be examined is that it is always decomposed when mixed with water.

If pure crystallized protosulphate of iron be dissolved in

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* Kirwan on Mineral Waters, Table IV.

† By my analysis.

‡ Berzelius, Ann. de Chim. lxxxii. 120.

§ Theoretical composition, on the supposition that it is composed of 1 atom acid, 1 atom protoxide, and 7 atoms water.

water acidulated with nitric acid and cautiously evaporated to dryness, taking care to drive off the whole of the nitric acid; but not using a temperature sufficiently high to disengage any of the sulphuric acid, the protoxide of iron is converted into peroxide. If water be poured upon this mass three-fourths of it are dissolved, and the remaining fourth is insoluble in water. This insoluble portion is a reddish yellow powder without either taste or smell. Probably green vitriol might be converted into this matter by a cautious application of heat. It is composed of

Subbipersulphate.

Red oxide of iron	20	80
Sulphuric acid	5	20
	25	100

Now an atom of red oxide of iron weighs 10, and an atom of sulphuric acid 5. Hence it is obvious, that the powder is a compound of 2 atoms base + 1 atom acid. Or it is a subbipersulphate.

The portion dissolved in water has a red colour with a tint of yellow. Its taste is intensely astringent and very harsh. When evaporated to dryness, and exposed to the air it speedily attracts moisture and deliquesces. It is soluble in alcohol. It does not crystallize. When exposed to rather a strong heat it lets go a portion of its acid. If we now pour water on it, a part remains undissolved in the state of subbipersulphate. The constituents of the soluble salt are,

Peroxide of iron	30	40
Sulphuric acid	45	60
		100

Now 30 peroxide of iron amount to 3 atoms, and 45 sulphuric acid amount to 9 atoms. Therefore the salt is composed of three atoms peroxide and 9 atoms sulphuric acid, or which is the same thing of 1 atom peroxide + 3 atoms acid. It is therefore a tripersulphate of iron.

When peroxide of iron obtained from the pernitrate by ammonia is dissolved in sulphuric acid, and the solution evaporated to the consistence of a syrup, it gradually deposits octahedral crystals. These crystals are transparent and colourless and have a taste exactly resembling that of alum. They dissolve readily in water. When heated they undergo the watery fusion and immediately become red. If the water of crystallization be driven off by heat they are divided into two portions, one of which is soluble and the other insoluble in water. The constituents of this salt, according to the analysis of Mr. Cooper, are as follows:

Sulphuric acid	31·58
Peroxide of iron	15·79
Water	52·63
	100·00*

We see that the weight of the acid is just double that of the oxide. Hence if we reckon the weight of an atom of peroxide of iron 10 the salt will be a quadripersulphate. But if we make the weight of an atom of peroxide of iron 5 the salt will be a *bipersulphate.*

This salt was first obtained in crystals by Mr. Rainey of Glasgow. Mr. Sylvester of Derby appears also to have been acquainted with it. But it was first obtained in quantities, and its nature ascertained, by Mr. Cooper.

Mr. Cooper has obtained likewise another persulphate of iron containing more acid, which crystallizes in white plates, and rather deliquesces on exposure to the air; but he has not yet succeeded in obtaining it in a state of sufficient purity for analysis.†

Sp. 6. *Sulphite of iron.* This salt can only be formed by dissolving recently precipitated protoxide of iron in sulphurous acid. It is insoluble in alcohol, and when exposed to the air is converted into sulphate of iron.

Sp. 7. *Hyposulphite of iron.* Sulphurous acid attacks iron with rapidity, much heat is produced, and the solution assumes at first a brown colour, which gradually passes into a green. During this solution no hydrogen gas is emitted except a few bubbles at first. The iron is oxidized at the expense of the acid, half the oxygen of which combines with the iron, and converts it into black oxide, while the whole sulphur and the remaining oxygen unite with the iron. The salt, therefore, which is obtained by this process, is not sulphite of iron, but hyposulphite. These phenomena were first described by Berthollet.‡ When sulphuric acid or muriatic acid is poured into this solution, sulphurous acid is disengaged with effer-

7. Hyposulphite.

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* Annals of Philosophy, xiii. 298.

† Ibid.

‡ Ann. de Chim. ii. 58.

vescence; and if these acids be added in sufficient quantity, a portion of sulphur is precipitated.

Varieties.

When the solution is exposed to the air, crystals of hyposulphite of iron are formed, and at the same time a red powder is deposited, probably consisting of *perhyposulphite* of iron with excess of base. The crystals dissolved in water and exposed to the air are gradually converted into sulphate of iron.*

Mr. Herschell has ascertained that this salt is formed when carbonate of iron is dissolved in sulphurous acid, and the liquid boiled over flowers of sulphur. Its taste is strongly ferrugenous. It does not crystallize, but yields a glutinous mass of a dirty white colour not unlike glazier's putty.†

8. Seleniate.

Sp. 8. *Seleniate of iron.* Of this salt there are four subspecies, namely,

1. Protoseleniate of iron,
2. Biprotoseleniate of iron,
3. Perseleniate of iron,
4. Biperseleniate of iron.

(1.) *Protoseleniate.* Selenic acid scarcely dissolves iron; but the salt may be formed by mixing solutions of a protosalt of iron and an alkaline seleniate. It precipitates in the form of a white matter which gradually becomes yellow as the air acts upon it. When muriatic acid is poured on it, and heat applied the acid is decomposed and selenium disengaged.

(2.) *Biprotoseleniate* is formed when the preceding salt is dissolved in selenic acid, or when a protosalt of iron is mixed with an alkaline biseleniate. It is but little soluble and gradually falls down. When a solution containing it is heated, this salt is decomposed, and a brown precipitate falls.

(3.) Perseleniate is easily obtained by dropping an alkaline seleniate into a persalt of iron. It is a white powder, which becomes yellowish on being dried. When heated it gives out its water and becomes red, and at a high temperature the acid may likewise be disengaged.

(4.) When iron is dissolved in a mixture of selenic acid and nitromuriatic acid at the boiling temperature, taking care that the whole of the nitric acid is not decomposed, the liquid deposits during its cooling, a salt of a pistachio green colour on the sides of the vessel. This salt, which is insoluble in water, Berzelius considers as a biperseleniate of iron.

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* Fourcroy, vi. 200.

† Edin. Philos. Jour. i. 22.

When either of the two preceding salts is digested in ammonia a portion of the acid is separated, and a *subperseleniate* formed, which passes through the filter, and which may be deprived of its acid by the action of heat.*

9. Arseniate.

Sp. 9. *Arseniate of iron.* Arsenic acid dissolves iron when assisted by a digesting heat; and if the experiment be made in an open vessel, the solution at last assumes the form of a jelly; but in a close vessel this does not happen. When one part of iron-filings and four parts of arsenic acid are distilled together to dryness, inflammation takes place, and at the same time both arsenic and white oxide of arsenic are sublimed.† Arsenic acid, as we see from these facts, is capable, like other acids, of combining with both the oxides of iron, and of forming *arseniate* of iron and *perarseniate* of iron. Both of these salts have been found native in Cornwall, and have been described and analysed with great accuracy by Bournon and Chenevix.

1 *Arseniate of iron.* This salt may be formed by pouring arseniate of ammonia into sulphate of iron. The salt precipitates in the state of a powder, insoluble in water. It exists native crystallized in cubes, which in some instances have their alternate angles truncated. Their colour is usually dark green, and their specific gravity 3.‡ When heated, the iron attracts oxygen from the acid, and passes to the state of red oxide, while white oxide of arsenic sublimes. This native salt is usually contaminated with a little copper. The artificial arseniate, according to the analysis of Chenevix, is composed of

38	acid
43	oxide
19	water
100	

The native (abstracting the impurities) was found by the same accurate chemist to be composed of about

36	acid
52	oxide
12	water
100§	

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* Berzelius, Ann. de Chim. et de Phys. ix. 337.

† Scheele, i. 177.

‡ Bournon, Phil. Trans. 1801, p. 190.

§ Ibid. p. 220.

2. *Perarseniate of iron.* This salt may be formed by precipitating persulphate of iron with arseniate of ammonia, or by boiling the arseniate of iron in nitric acid. The native arseniate is sometimes found converted into this salt, in consequence of the absorption of oxygen from the air, it has then a brownish-red colour. According to the analysis of Chenevix, the artificial perarseniate is composed of

42·4	acid
37·2	oxide
20·4	water
100·0*	

10. Antimoniate. Sp. 10. *Antimoniate of iron.* Antimoniate of potash precipitates iron perfectly white, and the antimoniate of iron preserves its white colour as long as it is under water. But when dried in the open air it becomes yellowish grey. When heated it gives out water and becomes red. Before the blow-pipe on charcoal it is reduced, the antimony is volatilized, and the iron remains obedient to the magnet.†

Sp. 11. *Chromate of iron.* When chromate of potash is dropped into sulphate of iron, a fawn-coloured precipitate falls, which contains oxide of chromium. Hence it appears that the black oxide of iron decomposes chromic acid. Chromate of iron then does not exist.‡ Probably we might form a perchromate by substituting persulphate of iron for the protosulphate.

Sp. 12. *Molybdate of iron.* The alkaline molybdates precipitate iron brown from its solution in acids.§

Sp. 13. *Tungstate of iron.* This salt exists native, and is known to mineralogists by the name of *Wolfram.* It may be formed by precipitating sulphate of iron by means of the tungstates. It is an insoluble powder, possessing properties similar to native tungstate of iron. As this native salt contains also manganese, and is not therefore a pure tungstate of iron, it will be proper to defer the description of it to the Second Part of this Work.

14. Acetate. Sp. 14. *Acetate of iron.* The acetic acid dissolves iron with rapidity, producing an effervescence, and, like the other acids, it forms a salt with each of the oxides of that metal; but the

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* Phil. Trans. 1801, p. 225.

† Berzelius, Nicholson's Journal, xxxv. 42.

‡ Vauquelin, Ann. de Chim. lxx. 70.

§ Scheele, i. 248.

properties of these salts have not been examined with attention.

1. *Acetate of iron.* This salt, as Davy affirms, may be easily procured by dissolving sulphuret of iron in acetic acid.* It yields by evaporation crystals of a green colour, in the form of small prisms. It has a sweetish styptic taste, and its specific gravity is 1·368.† By exposure to the air, or by the application of heat, it is converted into *peracetate.* During this change a red subperacetate is precipitated.

2. *Peracetate of iron* is a reddish-brown solution, incapable of yielding crystals, and assumes the form of a jelly when evaporated. It is deliquescent. This salt is much employed by calico printers, because it is more easily decomposed than any other of the oxygenized salts of iron. They prepare it either by mixing together sulphate of iron and acetate of lead, and leaving the solution exposed to the air, or by dissolving iron in an impure acetic acid, obtained by distilling wood.

The acetates of iron are decomposed by heat, and the iron left in the state of red or black oxide, according to the temperature.

Sp. 15. *Benzoate of iron.* A yellow powder insoluble in water. According to Trommsdorf, there exists a superbenzoate soluble in water and alcohol, capable of crystallizing and efflorescing in the air.‡

16. Succinate.

Sp. 16. *Succinate of iron.* Succinic acid dissolves the oxide of iron, and yields by evaporation small brown transparent radiated crystals.§ Persuccinate of iron is insoluble in water. Succinic acid accordingly separates iron from all other solutions. When succinate of soda is dropped into solutions containing peroxide of iron, a brownish red precipitate falls in light flakes, which is a persuccinate of iron. This salt is composed of

61·5	acid and water
38·5	oxide
100·0‖	

Gehlen has shown, that by means of succinate of soda, iron may be very completely separated from manganese. To suc-

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* Journal of the Royal Institution, i. 308.

† Hassenfratz, Ann. de Chim. xxviii. 12.

‡ Ann. de Chim. xi. 314.

§ Wenzel's Verwandtschaft, p. 240. Grindel's Edit.

‖ Gehlen, Klaproth's Beitrage, iii. 63.

ceed, the solution must be neutral, and the iron oxidized to a maximum.*

Sp. 17. *Boletate of iron.* Boletate of ammonia occasions no precipitate in protosulphate of iron; but it throws down the whole of the iron from the persulphate in the state of a red powder. As it does not throw down lime, alumina, or manganese, this salt may be employed therefore to separate iron from other bodies.†

Sp. 18. *Suberate of iron.* Suberic acid gives a deep yellow colour to sulphate of iron, but occasions no precipitate.‡

19. Oxalate. Sp. 19. *Oxalate of iron.* Oxalic acid attracts iron rapidly, and dissolves it with effervescence, and forms a peculiar salt with each of its oxides.

1. *Oxalate* is obtained by dissolving iron or its black oxide in that acid, and evaporating the solution. Prismatic crystals, of a green colour and sweet astringent taste, are formed, very soluble in water with an excess of acid, which fall to powder when heated. They are composed of

55	acid
45	oxide
100	

2. *Peroxalate* may be obtained by dissolving red oxide of iron in oxalic acid, or by exposing the first salt to the air in a digesting heat. It has the form of a yellow powder scarcely soluble in water, and incapable of crystallizing.§

Oxalic acid readily dissolves the oxides of iron even when combined with gallic acid. Hence it is often used to take spots of ink out of linen; and superoxalate of potash is usually sold in this country for that purpose, under the name of *essential salt of lemons.*

Sp. 20. *Mellate of iron.* Mellitic acid precipitates iron from nitric acid in the state of an Isabella yellow powder, which is redissolved by the addition of muriatic acid.||

Sp. 21. *Tartrate of iron.* Tartaric acid dissolves iron with effervescence, and combines with each of its oxides.

1. *Tartrate of iron* may be formed, according to Retzius,

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* Bucholz, Gehlen's Jour. ii. 515.

† Braconnot, Ann. de Chim. lxxx. 278.

‡ Bouillon Lagrange, Ann. de Chim. xxiii. 48.

§ Bergman, i. 268.

|| Klaproth's Beitrage, iii. 131.

by pouring tartaric acid into sulphate of iron, and applying heat to the solution. Lamellar crystals are formed, sparingly soluble in water, which possess the properties of tartrate of iron.

2. *Pertartrate* is usually formed when iron is dissolved in tartaric acid, and heat applied to the solution. It has a red colour, does not crystallize, but assumes the form of a jelly when evaporated.

Sp. 22. *Citrate of iron.* Both the oxides of iron combine with citric acid.

Citrate of iron may be obtained by dissolving iron filings in a solution of citric acid till the acid is saturated, taking care that air is excluded from the liquid during the solution. The solution is nearly colourless and deposits a white powder on standing, which is citrate of iron. It has an astringent and sweet taste; dissolves readily in water; but is insoluble in alcohol. When exposed to the air it speedily attracts oxygen, and becomes first yellow and then olive-green, being converted into percitrate.

During the solution of the iron a white crystalline matter is deposited, which has an acid and astringent taste, and is a bicitrate of iron. It is not nearly so speedily converted into percitrate as the neutral citrate.

The solution of percitrate of iron is olive-green. When evaporated to dryness it leaves a dark-brown, viscid, uncrystallizable salt, which, when hot, resembles melted rosin; but it becomes hard on cooling, and has an astringent taste accompanied with sweetness. It speedily deliquesces, and dissolves readily in water.

Sp. 23. *Saclactate of iron.* Saclactic acid does not precipitate iron from sulphuric acid.*

Sp. 24. *Malate of iron.* Malic acid forms with iron a brown solution, which does not yield crystals.†

Sp. 25. *Lactate of iron.* Lactic acid dissolves iron with rapidity when assisted by heat. The solution, when left to itself, lets fall a great number of small crystals in the shape of fine four-sided needles. This salt is not altered by exposure to the air. It is scarcely soluble in water, and contains hardly any water of crystallization. When held to the flame of a candle it does not melt, but burns with flame, and leaves peroxide of iron. Its colour is at first white; but when two or

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* Scheele, ii. 80.

† Scheele, Crell's Annals, ii. 10. Eng. Trans.

three times dissolved in water it is divided into two subspecies; the first, which has a brown colour, is soluble in water and crystallizes with difficulty. The other, which contains an excess of oxide, is white.

Lactic acid united to peroxide of iron furnishes a brown incrystallizable salt.*

26. Gallate.

Sp. 26. *Gallate of iron.* Mr. Proust first observed, that the gallic acid does not occasion any precipitate when poured into salts of iron containing that metal in the state of black oxide. Hence it follows that the gallate of iron, if it be formed in these cases, is very soluble in water and without colour; but when gallic acid is poured into the oxygenized salts of iron, the solution becomes black, and a black precipitate, composed of gallic acid and red oxide of iron, immediately begins to fall: but it is so very fine and light, that the greater part of it remains long suspended; and if a quantity of mucilage or syrup be mixed with the solution, the precipitate remains suspended altogether. It is the solution which constitutes writing ink. But ink is usually made by mixing the sulphate of iron of commerce with a saturated solution of nut-galls. Now the sulphate of commerce is a mixture of sulphate and persulphate of iron. That part of the iron which is in the state of sulphate forms at first a colourless solution; but by attracting oxygen from the atmosphere, it gradually becomes black. Hence the reason that ink is often pale at first, but becomes black when the writing dries, in consequence of the absorption of oxygen.

Writing ink.

Gallate of iron is soluble in acids without decomposition, but it loses its colour in very strong acids. Hence the reason that these acids destroy the colour of writing.

Sp. 27. *Ferro-sulphate of potash.* This salt may be formed by boiling together supersulphate of potash and iron-filings, and crystallizing the solution. It has been described by Link. The crystals resemble those of green vitriol. They effloresce in the air.†

Sp. 28. *Ferrophosphate of ammonia.* This triple salt has been mentioned by Fourcroy. It was obtained by dissolving the phosphate of iron in nitric acid, and precipitating by ammonia. An excess of that alkali redissolves the precipitate, but it appears again when the liquid is boiled for a sufficient

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* Braconnot, Ann. de Chim. lxxxvi. 94.

† Crell's Annals, 1796, i. 30,

length of time. It is a compound of phosphate of iron and ammonia.*

Sp. 29. *Ferrotartrate of potash.* This triple salt was formerly called *tartarised tincture of Mars, chalybeated tartar,* and *tartarised iron.* It may be formed by boiling two parts of tartar and one of iron-filings, previously made into a paste, in a proper quantity of water. The liquor by evaporation deposits crystals which form the salt wanted.

Sp. 30. *Ferromuriate of ammonia.* This salt, which has been long known, is obtained by dissolving in water 16 parts of sal ammoniac, and one part of permuriate of iron, evaporating the solution to dryness, and subliming. The yellowish mass sublimed is the triple salt. Its properties have not been examined with care.

* * *

Such are the properties of the salts of iron as far as they have been ascertained. The composition of the protosalts of iron is easily determined by considering them as compounds of 1 atom protoxide + 1 atom of each of the acids. An atom of protoxide of iron weighs 4·5, and the weight of an atom of each of the acids has been given in a preceding chapter of this volume. The composition of the persalts of iron is not so well understood. None of them has been analyzed, except the persulphate. I am inclined, at present, to the opinion that the peroxide of iron weighs 10, but its true weight can only be determined by a careful analysis of several of the salts into which it enters.

The two most useful salts of iron are the sulphate and acetate. Both of which are employed in great quantities in dyeing and calico-printing. The sulphate constitutes the colouring ingredient of ink and of prussian blue. Scarcely any of the other salts of iron have been applied to any useful purpose connected with domestic economy.

SECT. XVIII.

SALTS OF NICKEL.

The scarcity of nickel, and the difficulty of obtaining it in a state of purity, have hitherto prevented the possibility of an

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* Ann. de Chim. l. 200.

accurate examination of the combinations which its oxide forms with acids. The salts of nickel, therefore, are at present but very imperfectly known. They may be distinguished by the following properties:

Characters. 1. Its salts are in general soluble in water, and the solution has a beautiful green colour.

2. Ferrochyazate of potash, when dropped into these solutions, occasions a precipitate of a milk-white colour.

3. The hydrosulphuret of potash occasions a black precipitate.

4. Sulphuretted hydrogen gas occasions no precipitate.

5. Gallic acid, and the infusion of nut-galls, occasion no precipitate, at least in the sulphate of nickel.

1. Nitrate. Sp. 1. *Nitrate of nickel.* Nitric acid dissolves nickel or its oxide when assisted by heat. The solution has a green colour, and yields by evaporation nitrate of nickel in the form of rhomboidal crystals, which, on exposure to the air, at first deliquesce, but afterwards fall to powder, and gradually lose their acid, so that only the oxide of nickel remains behind.[*] The nitrate of nickel contains the protoxide of that metal. If it be distilled cautiously, a subnitrate may be obtained, insoluble in water, and composed, according to the analysis of Proust, of

Nickel	100	125
Oxygen	25	
Acid		17
		142[†]

The nitrate of nickel, according to the same chemist, is composed of

55	acid
25	oxide
20	water
100	

The constituents of this salt, supposing it a compound of 1 atom protoxide of nickel + 1 atom acid + 3 atoms water ought to be

Nitric acid	46·55
Protoxide of nickel	30·17
Water	23·28
	100·00

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[*] Bergman, ii. 268.

[†] Ann. de Chim. lx. 273.

Were we to suppose Proust's analysis of the subnitrate nearly correct, it would be a compound of 1 atom acid and 11 atoms of oxide. But the existence of such a compound as a salt does not seem very probable. What he examined was in all probability merely a mixture of subnitrate of nickel (composed of 2 atoms oxide and 1 atom acid) and oxide of nickel.

Sp. 2. *Ammonio-nitrate of nickel.* This triple salt, first pointed out by Thenard, is obtained by adding ammonia in excess to the nitrate of nickel. By evaporation a green coloured salt is obtained in crystals. The solution of this salt in water is not rendered turbid by alkalies; but the nickel is thrown down by hydrosulphurets.*

3. Carbonate.

Sp. 3. *Carbonate of nickel.* It does not appear from the experiments of Bergman, that carbonic acid is capable of combining with nickel directly. When 100 parts of pure nickel are dissolved in nitric acid, and precipitated by carbonate of potash, the precipitate weighs when dried 293 parts; but when heated to redness it becomes 128. Hence carbonate of nickel must be composed of

56·4	acid and water
43·6	oxide
100·0 †	

According to Proust the oxide amounts to 54 per cent. in this salt.‡ If we suppose the carbonate of nickel a compound of 1 atom acid + 1 atom base, it is obvious that its constituents must be

Acid	38·6
Oxide	61·4
	100·0

To reconcile this with Richter's statement, we must suppose the salt to contain 29 per cent. of water. The probability is, that it contains 3 atoms of water, which would make the composition as follows:

Carbonic acid	26·19
Protoxide of nickel	41·66
Water	32·15
	100·00

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* Ann. de Chim. xlii. 217.

† Richter, Gehlen's Jour. iii. 258.

‡ Ann. de Chim. lx. 276.

Sp. 4. *Borate of nickel.* Boracic acid can only be combined with nickel by mixing an alkaline borate with a solution of nickel in some acid.

Sp. 5. *Phosphate of nickel.* Phosphoric acid is capable of dissolving only a very small portion of the oxide of nickel. The solution does not yield crystals, and has scarcely even a green colour.* Hence it would seem that the phosphate of nickel is nearly insoluble.

6. Sulphate.

Sp. 6. *Sulphate of nickel.* Sulphuric acid scarcely attacks pure nickel, but the solution is easily effected by dropping a little nitric acid occasionally into the sulphuric acid as the effervescence stops. If the impure nickel of commerce be employed, we find, when the solution is completed, a considerable quantity of arsenious acid at the bottom of the vessel. Decant off the clear solution and concentrate it sufficiently. A fine crop of beautiful green crystals of sulphate of nickel is obtained. Dissolve these crystals in water, and crystallize a second time. The crystals thus obtained consist of sulphate of nickel sufficiently pure for chemical purposes. This salt crystallizes in four-sided rectangular prisms, terminated by three and six-sided irregular pyramids. The taste is astringent and somewhat similar to that of sulphate of manganese; but not so strong. The salt is very soluble in water. The crystals are not altered by exposure to the air. When heated they swell up; but do not melt, and they assume a yellow colour, owing to the escape of the water. After this treatment, the salt dissolves again in water; but in general a little insoluble subsulphate is left behind. It is composed of 1 atom acid + 1 atom oxide + 7 atoms water, or by weight of

Sulphuric acid	28·98
Protoxide of nickel	25·36
Water	45·66
	100·00

I have obtained this salt, occasionally crystallized, in flat rectangular prisms about half an inch in length, terminated at each end by dihedral summits, having the angle at their apex about 79°. The respective dimensions of this crystal are as follows:

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* Bergman, ii. 268.

Length	53
Breadth	25
Thickness	13
Length of apex ...	3

The colour of these crystals is grass green. They are transparent, and have a taste similar to the common sulphate of nickel. I have never obtained a sufficient quantity of these crystals to subject them to a regular analysis. But I did not detect any other ingredient in them except sulphuric acid and oxide of nickel.

Sp. 7. *Ammonio-sulphate of nickel.* When ammonia is poured into the solution of sulphate of nickel, a triple salt is formed, which yields by evaporation crystals of a green colour, consisting of four-sided flat prisms terminated by four-sided pyramids.*

Sp. 8. *Sulphate of nickel-and-potash.* This salt was first described by Proust, who availed himself of its properties as a means to separate nickel and cobalt; a problem which has long occupied the attention of chemists.† It may be formed by dropping potash into a solution of sulphate of nickel. By evaporation the triple salt is obtained in crystals. It is sparingly soluble in water. The crystals are transparent rhomboids of a beautiful emerald colour. By dissolving this salt in water, and crystallizing it repeatedly, the sulphate of cobalt is left behind in the mother water, being much less disposed to crystallize than the triple salt of nickel. The taste of the sulphate of nickel-and-potash is sweet like that of sugar of milk; but it leaves in the mouth a sensible acridity.‡

When this salt is heated it loses 24 per cent. of water. It contains only 15 per cent. of oxide of nickel.§ From these data it is probable that it is a compound of 1 atom sulphate

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* Link, Crell's Annals, 1796, i. 32.

† The most elegant method of separating these two metals seems to be that of Thenard. The mixture of the two metals is to be thrown down by an alkaline carbonate, and then treated with oxymuriate of lime. The cobalt is converted into a peroxide insoluble in ammonia, but the nickel is still soluble. Digest in ammonia. The nickel alone is taken up. Drive off the ammonia; dissolve the oxide in nitric acid, and crystallize. Ann. de Chim. l. 117.

‡ Proust, Jour. de Phys. xlvii. 169.

§ Proust, Ann. de Chim. lx. 271.

of potash, 1 atom sulphate of nickel, and 6 atoms of water, or by weight of

Sulphate of potash	40·55
Sulphate of nickel	34·56
Water	24·89
	100·00

Sp. 9. *Sulphate of nickel-and-iron.* This salt may be obtained by mixing together the solutions of nitrate of nickel and sulphate of iron, and evaporating the mixture; or by dissolving at once the oxides of nickel and iron in sulphuric acid. The salt crystallizes in tables; its colour is green; and it effloresces when exposed to the atmosphere.*

Sp. 10. *Seleniate of nickel.* The neutral salt is an insoluble powder, white while moist; but becoming pale apple-green when dried. The *biseleniate* is soluble, and gives a green matter resembling gum.†

11. Arseniate.

Sp. 11. *Arseniate of nickel.* Arsenic acid does not appear capable of dissolving pure nickel. The arseniate of this metal is soluble in water. Hence nickel is not precipitated from its solutions either by arsenic acid or the arseniates.‡ This arseniate has an apple-green colour. When heated in a glass tube it loses its colour with its water, and becomes hyacinth-coloured and transparent. When heated to redness it becomes bright yellow and remains unaltered.§

12. Chromate.

Sp. 12. *Chromate of nickel.* Chromic acid dissolves the carbonate of nickel in considerable quantity; but after some hours a pulverulent precipitate falls from the clear solution, which is again soluble in an excess of acid. This precipitate is probably a chromate of nickel. The acid solution gives by slow evaporation fern-leaved crystals in the state of eliptical plates, truncated on both sides, which towards the beginning and end of the leaf-stalks becomes smaller, so as to preserve the resemblance. When these crystals are exposed to a high temperature the acid is decomposed and a black mass formed,

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* Link, Crell's Annals, 1796, i. 32.

† Berzelius, Ann. de Chim. et de Phys. ix. 339.

‡ The precipitates mentioned by Bergman and Scheele, as appearing when solutions of nickel were mixed with arseniate of potash, were doubtless arseniate of bismuth; for that metal is usually present in solutions of impure nickel.

§ Proust, Ann. de Chim. lx. 278.

which is insoluble in water and consists of oxide of chromium and oxide of nickel.*

Sp. 13. *Molybdate of nickel.* Molybdic acid precipitates nitrate of nickel white, provided there be no excess of nitric acid.†

14. Acetate.

Sp. 14. *Acetate of nickel.* Acetic acid dissolves nickel, and forms with its oxide rhomboidal crystals of a very green colour.‡ It is very soluble in water. The solution has a darker colour than the crystals. When heated its acid is disengaged and it becomes black. It loses, when thus treated, 62·61 per cent. of its weight. A considerable quantity of carbonic acid and carbureted hydrogen is disengaged, and a little acetic acid comes over undecomposed.§

Sp. 15 and 16. *Benzoate and succinate of nickel.* Neither benzoate nor succinate of ammonia occasion any precipitate in sulphate of nickel. Hence it is probable, that both the benzoate and succinate of nickel are soluble in water.

17. Oxalate.

Sp. 17. *Oxalate of nickel.* Oxalic acid attacks nickel at a digesting heat, and a greenish white powder is deposited, which is the oxalate of that metal. The same salt is precipitated when oxalic acid is dropped into the solution of nickel in sulphuric, nitric, or muriatic acids. It is scarcely soluble in water, and is composed, according to Bergman, of 2 parts of acid to 1 of metal.‖ This would indicate a binoxalate.

Sp. 18. *Tartrate of nickel.* Tartaric acid does not attack nickel.** The compound which it forms with its oxide has not been examined. Neither are we acquainted with any of the remaining species of the combustible salts of nickel.

Sp. 19. *Sulphate of nickel-copper-and-iron.* This salt is said by Link to be formed when the solution of nickel in nitric acid is mixed with sulphate of copper. It crystallizes, according to him, in blue-coloured prisms terminated by four-sided pyramids, and when exposed to the air falls to powder; but his experiments would require to be verified by repetition.††

The salts of nickel would require a more rigorous examination than they have hitherto undergone. Chemists have

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* John, Annals of Philosophy, iv. 426.

† Hatchett, Phil. Trans. 1796.

‡ Bergman, ii. 268.

§ Chenevix, Ann. de Chim. lxix. 16 and 20.

‖ Bergman, ii. 269.

** Ibid.

†† Link, Crell's Annals, 1796, i. 31.

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been deterred from studying them by the difficulty of obtaining the oxide of nickel in a state of sufficient purity. Sulphate of nickel obtained by the process described in this section, will afford a cheap method of procuring this oxide, sufficiently pure for experiments.

The composition of the salts of nickel may be determined by considering them as compounds of 1 atom protoxide of nickel and 1 atom of each of the acids. An atom of protoxide of nickel weighs 4·375, and the weight of the acids has been given in a preceding chapter of this volume.

None of the salts of nickel have as yet been applied to any useful purpose.

SECT. XIX.

SALTS OF COBALT.

The salts of cobalt have attracted the attention of chemists, in consequence of the property which some of them have of changing their colour when heated, and thus forming what has received the name of *sympathetic ink;* an appellation given to all liquids, the characters formed by which are colourless and invisible when written upon paper, but become visible and coloured by undergoing certain processes; and likewise to those liquids which form characters upon paper susceptible of changing their colour by certain processes. It is probable that chemists have not hitherto had an opportunity of often examining the pure salts of cobalt; for several of the other metals adhere to cobalt with such persevering obstinacy, that it is very difficult to obtain it in a separate state. The salts of cobalt may be distinguished by the following properties:

Characters.

1. The greater number of them are soluble in water, and the solution has a reddish colour, at least when the salts are neutral.*

2. The alkalies, when dropped into these solutions, occasion a blue-coloured precipitate.†

3. Ferrochyazate of potash occasions a light-green precipitate.

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* The solution of cobalt in muriatic acid, when concentrated, has a bluish-green colour as long as there is an excess of acid.

† When the cobalt is contaminated with arsenic acid, or when it is dissolved in arsenic acid, the precipitate by alkalies is reddish-brown.

4. Hydrosulphuret of potash occasions a black precipitate, soluble again if the hydrosulphuret be added in excess. Sulphuretted hydrogen gas occasions no precipitate in these solutions.*

5. Gallic acid produces no change; but the tincture of nutgalls occasions a yellowish-white precipitate.

6. The ammoniacal solution of oxide of cobalt has the colour of port wine. It is not immediately precipitated by ferrochyazate of potash; but after some time a reddish precipitate falls.

7. The salts of cobalt are not precipitated by hydriodate of zinc.

8. Cobalt is not precipitated from its solution in acids by zinc.

1. Nitrate.

Sp. 1. *Nitrate of cobalt.* Nitric acid attacks cobalt when assisted by heat. The solution has a red colour, and yields by evaporation small prismatic crystals of a red colour, deliquescent in the air, and decomposed by heat, leaving a deep red powder.

2. Carbonate.

Sp. 2. *Carbonate of cobalt.* The fixed alkaline carbonates precipitate cobalt from its solutions in the state of a reddish-blue powder. This insoluble carbonate contains, according to Bergman, $\frac{1}{8}$th of its weight of carbonic acid.†

3. Borate.

Sp. 3. *Borate of cobalt.* Boracic acid does not act upon cobalt, but it precipitates that metal from its solution in other acids in the state of a reddish-white powder. This borate is scarcely soluble in water. When heated it melts into a deep blue glass.‡

4. Phosphate.

Sp. 4. *Phosphate of cobalt.* Phosphoric acid does not attack cobalt; but it dissolves its oxides, and forms a deep wine-red solution.§

5. Sulphate.

Sp. 5. *Sulphate of cobalt.* Sulphuric acid requires a boiling heat before it can attack cobalt: sulphurous acid gas is disengaged, and a brownish red mass remains, which dissolves with facility in water. Sulphuric acid dissolves the peroxide of cobalt with difficulty; bubbles of gas are emitted during this solution, which Thenard supposed to be oxygen.|| The solution is always red; and yields by evaporation small needle-

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* Proust, Ann. de Chim. xxxv. 51.

† Opusc. ii. p. 388 and 392. It contained arsenic acid, as is obvious from its red colour.

‡ Wenzel's Verwandtschaft, p. 253.

§ Gren's Handbuch, iii. 528.

|| Ann. de Chim. lxii. 211.

form crystals, consisting of rhomboidal prisms, terminated by dihedral summits. This salt has a reddish colour. It is soluble in 24 parts of water, but insoluble in alcohol.[*] This salt is not altered by exposure to the air. When heated, it loses 42 per cent. of water. The residue is rose-coloured and opaque. It may be exposed to a red heat in a retort without undergoing decomposition, except at those points which touch the glass.[†]

This salt, according to the analysis of Bucholz, is composed of

26	acid
30	oxide
44	water
100[‡]	

Supposing it a compound of 1 atom acid, 1 atom protoxide, and 7 atoms water, its constituents will be

Sulphuric acid	28·57
Protoxide of cobalt	26·43
Water................	45·00
	100·00

This species readily combines with sulphate of potash or sulphate of ammonia, and forms two species of triple salts, which have not hitherto been described with accuracy. The sulphate of potash-and-cobalt crystallizes in rhomboidal cubes. It is not so soluble in water as sulphate of cobalt, and yields only 26 per cent. of water when distilled.[§]

Sp. 6. *Seleniate of cobalt.* The neutral seleniate is an insoluble red-coloured powder. The biseleniate leaves when evaporated a red beautiful shining varnish.[||]

7. Arseniate.

Sp. 7. *Arseniate of cobalt.* Arsenic acid, when digested upon cobalt, acquires a red colour, but it does not dissolve the metal completely. Arsenic acid does not precipitate cobalt from its solution in acids; but the alkaline arseniates occasion a precipitate of a fine red colour, which is arseniate of cobalt.[**] This salt is found native: sometimes in the state of a fine red

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[*] Gren's Handbuch, iii. 524.

[†] Proust, Ann. de Chim. lx 260.

[‡] Beitrage, iii. 30.

[§] Proust, Ann. de Chim. lx. 260.

[||] Berzelius, Ann. de Chim. et de Phys. ix. 339.

[**] Scheele, i. 186.

efflorescence, and sometimes crystallized in small four-sided prisms or tables.

When the arseniate of cobalt is heated in a glass tube it becomes violet, but is not decomposed, nor does it tinge the glass blue. It dissolves in nitric acid without effervescence. When its solution in muriatic acid is mixed with sulphuretted hydrogen, it does not become turbid till it has stood two hours. Potash precipitates blue oxide of cobalt, and combines with the acid.*

Sp. 8. *Antimoniate of cobalt.* This salt is obtained by dropping antimoniate of potash into a salt of cobalt. It is a red coloured precipitate, which gradually contracts and assumes the form of crystalline grains. It is soluble in water, but not very much so. According to Berzelius, it is composed of

Antimonic acid	52
Oxide of cobalt	14
Water	33·3
	99·3 †

Sp. 9. *Antimonite of cobalt.* A bulky lilac coloured precipitate having no aspect of crystallization. It is pretty soluble in water. It contains 25 per cent. of water of crystallization.‡

10. Acetate. *Remaining species.*—10. Acetic acid dissolves the oxide of cobalt with facility. The solution does not crystallize; and when evaporated to dryness, soon deliquesces again. It has a fine red colour while cold, but becomes blue when heated.§ This solution forms a sympathetic ink: the characters drawn in it are colourless while cold, but become blue when heated.||

11. Oxalic acid attacks cobalt, and converts it into a red powder, which is oxalate of cobalt. This salt is insoluble in water, but it dissolves in an excess of acid, and yields crystals. Oxalic acid precipitates an oxalate of cobalt from the solution of that metal in most acids.**

12. Tartrate. 12. Tartaric acid dissolves the oxide of cobalt, and forms a red solution which yields crystals.†† When tartrate of pot-

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* Proust, Ann. de Chim. lx. 271.

† Nicholson's Journal, xxxv. 42.

‡ Berzelius, Nicholson's Journal, xxxv. 45.

§ Wenzel's Verwandtschaft, p. 150.

|| Isleman, Crell's Annals, 1785, ii. 25.

** Bergman, i. 270.

†† Gren. iii. 128.

ash is dropt into the solutions of cobalt, it precipitates the arseniates of iron and bismuth, if they be present, and they carry with them a portion of the cobalt. By spontaneous evaporation the liquid yields large rhomboidal crystals of tartrate of potash-and-cobalt.

13. Lactic. 13. Lactic acid readily dissolves the protoxide of cobalt. The solution is red, and when evaporated deposits crystalline crusts. The crystalline grains do not appear to contain any water of crystallization. They dissolve in 38 times their weight of water at 70°. When heated they do not melt but become black, take fire, and leave oxide of cobalt.*

Sp. 14. *Ammonio-nitrate of cobalt.* When a solution of cobalt in nitric acid is supersaturated with ammonia, it is well known that no precipitate appears. When this solution is evaporated to dryness, and the residue is treated with water, a red solution is obtained, which yields by slow evaporation regular cubes of a red colour. These crystals are a triple salt, composed of nitric acid, ammonia, and oxide of cobalt. They were first observed by Thenard. Their taste is urinous; they are not altered by exposure to the air. When heated they burn with a yellowish-white flame, like nitrate of ammonia, leaving an oxide of cobalt. Their solution in water is neither precipitated by alkalies nor alkaline earths; but when boiled with potash, ammonia is disengaged, and the oxide of cobalt precipitates.†

The salts of cobalt, as is evident from the preceding account of them, have been but imperfectly examined. Their composition is easily determined by considering them as compounds of 1 atom of protoxide of cobalt, and 1 atom of each of the acids. An atom of protoxide of cobalt weighs 4·625, the weight of the acids has been given in a preceding chapter of this volume. The salts of cobalt have not hitherto been applied to any useful purpose.

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* Braconnot, Ann. de Chim. lxxxvi. 89.

† Thenard, Ann. de Chim. xlii. 215.

SECT. XX.

SALTS OF MANGANESE.

Chap. II.

Most of the properties of this genus of salts with which we are even at present acquainted were ascertained by Bergman and Scheele, by whose labours the oxide of manganese, one of the most important of all our instruments, was first put into the hands of chemists, and by Dr. John who investigated the salts of manganese with some care.* The salts of manganese may be distinguished by the following properties:

Characters.

1. They are almost all soluble in water; and the solution, when treated with fixed alkalies, deposites a white or reddish-coloured precipitate, which very soon becomes black when exposed to the air.

2. Ferrochyazate of potash occasions a white precipitate when dropped into these solutions.

3. Hydrosulphuret of potash occasions a white precipitate. Sulphuretted hydrogen gas gives the solution a white colour, but produces no precipitate.

4. Gallic acid and infusion of nut-galls, occasion no precipitate.

5. Manganese is not precipitated from its solution in the metallic state by any of the other metals.

6. The salts of manganese are not precipitated by succinate or benzoate of ammonia.

1. Nitrate.

Sp. 1. *Nitrate of manganese.* Nitric acid dissolves manganese with effervescence, occasioned by the emission of nitrous gas. It dissolves the carbonate with facility, but it has very little action on the black oxide; however, by very long digestion, it at last dissolves a part of it. The solution goes on much more rapidly if a little sugar or gum, or any similar substance, be added, and at the same time a quantity of carbonic acid gas is emitted. Hence we see that the black oxide must part with a portion of its oxygen before nitric acid can dissolve it. Nitrous acid acts upon the black oxide much more readily, and is converted entirely into nitric acid. The solution, in what manner soever it has been made, is always colourless, provided the manganese be pure. Hence we may conclude that it contains only the protoxide. So that, as far

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* Gehlen's Journal für die Chemie, Physick, und Mineralogie, iii. 452.

as is known at present, there is no such substance as pernitrate of manganese.

By dissolving carbonate of manganese in nitric acid and evaporating cautiously, Dr. John obtained nitrate of manganese in needle-form crystals. Their colour was white, they were semitransparent, had a sharp bitter taste, were very soluble in water, deliquesced by exposure to the air, dissolved in alcohol, and the solution burnt with a green-coloured flame.*

2. Carbonate. Sp. 2. *Carbonate of manganese.* Carbonate of manganese is easily obtained by pouring carbonate of potash into a solution of sulphate or nitrate of manganese, a white powder precipitates which on drying acquires a slight shade of yellow. It is tasteless, is not altered by exposure to the air, and is insoluble in water. It is composed of

Carbonic acid	37·93
Protoxide of manganese	62·07
	100·00

When we dissolve it in acids there is always some black oxide separated.

3. Silicate. Sp. 3. *Silicate of manganese.* The mineral distinguished by the name of *foliated red manganese ore* appears to be in reality a silicate of manganese nearly pure. It has a rose-red or flesh-red colour, a foliated fracture, has a slight degree of translucency, is hard enough to scratch glass, and has a specific gravity of 3·5384. Its constituents, according to the analysis of Berzelius, are

Oxide of manganese	52·60
Silica	39·60
Oxide of iron	4·60
Lime	1·50
Volatile matter	2·75
	101·05†

Now, if we abstract the small quantity of iron, lime, and water which are present, the other ingredients approach very nearly to the proportions resulting from a combination of 2 atoms of silica with 1 atom of oxide of manganese. It is therefore a bisilicate of manganese. Berzelius mentions a silicate of manganese, distinguished among mineralogists by the

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[*] Gehlen's Journal, iv. 437.

[†] Afhandlingar, i. 105.

name of *svart mangankisel (black manganese flint.)* But I am not acquainted with it.[*]

Sp. 4. *Phosphate of manganese.* Phosphoric acid has but little action on manganese or its oxides, because it forms with them a salt difficultly soluble in water. But phosphate of manganese may be obtained in the form of a precipitate, by mixing an alkaline phosphate with the solution of manganese in any of the three mineral acids.[†] This salt has not been hitherto examined.

5. Sulphate.

Sp. 5. *Sulphate of manganese.* Sulphuric acid acts with little energy on manganese, even when diluted with two or three times its weight of water, and even when assisted by heat. It dissolves readily the protoxide of manganese: but it has no action whatever on the black oxide unless assisted by heat. When that is the case, oxygen gas passes off in abundance, and the oxide is dissolved. The same solution takes place without the emission of that gas when a little sugar is added to the mixture. So that we have two combinations of sulphuric acid and manganese; first, the combination of sulphuric acid and the protoxide, which forms sulphate of manganese; and, secondly, the combination of the acid with the peroxide, which constitutes persulphate of manganese.

1. *Protosulphate of manganese.* This salt is easily obtained by dissolving carbonate of manganese in sulphuric acid. It crystallizes in rhomboidal prisms which are not altered by exposure to the air. Its taste is rather sweetish with a very slight impression, similar to that of sulphate of zinc, 100 parts of water at the temperature of 40° dissolve 31 parts of this salt previously dried in the temperature of 150°. Its specific gravity is 2·877. It is insoluble in alcohol.[‡]

Sulphate of manganese is not precipitated by oxalate of potash, borate of soda, nor tartaric acid. Its constituents, according to John, are as follows:

Sulphuric acid	33·66
Protoxide of manganese	31·00
Water	35·34
	100·00[§]

If we suppose it a compound of 1 atom acid, 1 atom protoxide, and 5 atoms water, its composition must be as follows:

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[*] Afhandlingar, iv. 94.

[†] Scheele, i. 48—Bergman, ii. 219.

[‡] John, Annals of Philosophy, ii. 183.

[§] Ibid. ii. 114.

Sulphuric acid	33·05
Protoxide	29·75
Water	37·20
	100·00

Now these numbers come sufficiently near those of John to show that the composition of the salt is rightly stated.

2. *Persulphate of manganese.* This salt may be obtained by distilling sulphuric acid from the black oxide of manganese, and washing the residuum in water. A red or rather violet-coloured liquor is thus obtained, which holds in solution the persulphate of manganese. This solution is difficultly crystallized, but passes readily into a gelatinous form. The few crystals which are mixed with this jelly are soft, and have but little permanency. When evaporated to dryness, it yields thin red-coloured saline crusts, which precipitate successively from the surface, and which do not readily deliquesce. This salt is very soluble in water; and alkalies precipitate the manganese in the state of a red oxide, which soon becomes black when exposed to the air.*

Sulphurous acid readily dissolves the black oxide of manganese, and forms with it sulphate of manganese, as Scheele ascertained.† The theory of this is obvious. Part of its oxygen is abstracted from the manganese by the acid; in consequence of which, the black oxide is converted into white oxide, and the sulphurous into sulphuric acid. It is not known whether sulphurous acid forms with the oxides of manganese a permanent salt.

Haussman has proposed the sulphate of manganese for marking lines so as not to be effaced by the action of chlorine. The solution of this salt in water is mixed up with any vegetable colouring matter to the proper consistence, and applied to the linen, which is then passed through an alkaline ley. The oxide of manganese is thus precipitated upon the cloth; and by the action of chlorine, its colour becomes yellowish brown.‡

Sp. 6. *Hyposulphite of manganese.* This salt remains in solution when hyposulphite of lime is precipitated by sulphate of manganese.§

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* Bergman, p. 215.

† Scheele, i. 43.

‡ Ann. de Chim. liii. 208.

§ Herschell, Edin. Phil. Jour. i. 24.

Sp. 7. *Hyposulphate of manganese.* This salt is very soluble in water, and even deliquescent.*

Sp. 8. *Seleniate of manganese.* The neutral salt is a white, soft, insoluble powder. It is very fusible; but preserves its acid very well in close vessels. In the open air, on the contrary, the manganese absorbs oxygen, and allows the acid to make its escape. This salt attacks and corrodes glass much more violently than either the seleniate of lime or of magnesia.

The biseleniate is very soluble in water; by evaporation it yields a crystallizable saline mass. A high temperature drives off the excess of its acid.†

9. Arseniate.

Sp. 9. *Arseniate of manganese.* Arsenic acid dissolves the protoxide of manganese with facility; and when it approaches the point of saturation, the solution becomes thick, with small crystals, which separate. These crystals are arseniate of manganese. They are precipitated when an alkaline arseniate is dropped into the solution of manganese in an acid. These crystals do not melt when heated; neither does arsenic sublime, unless charcoal be mixed with them.‡ The arseniate of manganese is insoluble, unless there be an excess of acid present. Sulphuric acid dissolves it, and crystals are obtained, which constitute a triple salt.§

10. Antimoniate.

Sp. 10. *Antimoniate of manganese.* This salt is a white powder not altered by exposure to the air. It is very little soluble in water. When heated it gives out water and becomes grey. When the heat is carried nearly to redness, combustion takes place, and the salt becomes again white.‖

Sp. 11. *Chromate of manganese.* Chromic acid acts very slowly on manganese, but it dissolves the carbonate with effervescence. The solution is chesnut brown, and has a sharp metallic taste. It does not crystallize. When the solution is evaporated, the manganese together with a portion of the chromic acid falls in the state of a black powder.**

12. Tungstate.

Sp. 12. *Tungstate of manganese.* Tungstic acid and water boiled on powdered manganese convert it into a white powder, as it does likewise the carbonate of manganese. Tungstate of manganese may be obtained by dropping tungstate of potash

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* Gay-Lussac; Annals of Philosophy, xiv. 355.

† Berzelius; Ann. de Chim. et de Phys. ix. 206.

‡ Scheele, i. 188.

§ John, Gehlen's Jour. iv. 443.

‖ Berzelius, Nicholson's Jour. xxxv. 42.

** John, Gehlen's Jour. ibid. p. 141.

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into a solution of manganese. It is a tasteless white powder, insoluble in water, and not altered by exposure to the air. When heated it becomes yellow, and then brown, but does not melt.*

13. Acetate.

Sp. 13. *Acetate of manganese.* Acetic acid dissolves manganese and its carbonate very slowly. The solution readily crystallizes in beautiful rhomboidal tables. They have a reddish colour, are transparent, and not altered by exposure to the air. Their taste is astringent and metallic. They dissolve in 3½ times their weight of cold water. They are soluble likewise in alcohol. Their constituents according to John are 30 oxide, and 70 acid and water.† If we suppose it a compound of 1 atom acid, 1 atom protoxide, and 4 atoms water, its constituents must be

Acetic acid	41·46
Protoxide of manganese	29·33
Water	29·21
	100·00

14. Benzoate.

Sp. 14. *Benzoate of manganese.* Benzoic acid dissolves manganese and its carbonate slowly. The solution yields thin prismatic crystals, which are colourless, transparent, and are not altered by exposure to the air. They have a sweetish astringent taste, which leaves a bitterish impression. At the temperature of 66°, they require 20 times their weight of water to dissolve them. They are soluble likewise in alcohol. When distilled they yield a very little water, but a good deal of oil. According to John they are composed of 24 oxide and 76 acid and water.‡ Supposing it a compound of 1 atom acid + 1 atom protoxide, its constituents must be

Benzoic acid	76·92
Protoxide of manganese	23·08
	100·00

Hence it seems to follow from John's analysis, that benzoate of manganese contains no water of crystallization.

15. Succinate.

Sp. 15. *Succinate of manganese.* Succinic acid dissolves manganese and its carbonate very readily. The solution has a reddish colour and yields when evaporated crystals which are

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* John, Gehlen's Jour. xxxv. p. 442.

† Ibid. p. 440.

‡ Gehlen's Jour. ibid. p. 438.

sometimes four-sided prisms, sometimes four-sided tables, and sometimes octahedrons, composed of two four-sided pyramids applied base to base. These crystals are transparent. They appear colourless when viewed singly; but when laid in numbers above each other they assume a rose-red colour. When heated they become opake, white, and similar in appearance to porcelain. They are insoluble in alcohol. At the temperature of 66° they require ten times their weight of water to dissolve them. When distilled they yield water, brown oil, and an inflammable gas. According to John they are composed of 30·27 protoxide of manganese and 69·73 acid and water.* Supposing this salt a compound of 1 atom acid and 1 atom protoxide, its composition must be

Succinic acid	58·13
Protoxide of manganese	41·87
	100·00

When we compare these numbers with the analysis of John, it is evident that the crystals of succinate of manganese are composed of 1 atom acid, 1 atom protoxide, and 4 atoms water.

16. Oxalate. *Remaining species.*—16. Oxalic acid attacks manganese, and dissolves the black oxide with effervescence. The solution, when saturated, lets fall the oxalate of manganese in the state of a white powder. Oxalic acid precipitates the same powder from the solution of manganese in sulphuric, nitric, or muriatic acid.†

17. Tartrate. 17. Tartaric acid dissolves black oxide of manganese cold; but the solution is blackish: When heated, an effervescence ensues, owing to the decomposition of part of the oxide and the escape of carbonic acid gas; and the solution becomes colourless.

18. Citrate. 18. Citric acid acts upon the black oxide of manganese exactly as tartaric acid.‡

19. *Tartrate of potash-and-manganese.* When tartrate of potash is mixed with a solution of manganese, no immediate change takes place; but if the mixture be set aside, a great number of small prismatic crystals of a reddish brown colour are deposited, consisting of tartrate of potash combined with

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* Gehlen's Journal, xxxv. p. 439.

† Bergman, i. 272, and ii. 219.

‡ Bergman, ii. 220.

the oxide of manganese. They are sparingly soluble in water. Heat decomposes them by destroying the acid. Richter proposed the formation of this salt as one of the best means of procuring an oxide of manganese in a state of purity; but succinate of potash answers the purpose better, by effectually separating the iron, the only metal with which manganese is contaminated in common cases.

SECT. XXI.

SALTS OF CERIUM.

For the facts respecting this genus of salts at present known, we are chiefly indebted to the labours of Klaproth, Hisinger, Berzelius, and Vauquelin. The salts of cerium possess the following properties:

Characters.

1. They are either white or yellow-coloured, according to the state of oxidizement of the oxide.

2. Their solutions in water have a sweet taste.

3. Hydrosulphuret of potash occasions only a white precipitate consisting of the oxide of cerium. Sulphuretted hydrogen occasions no precipitate.

4. Ferrochyazate of potash occasions a milk-white precipitate, soluble in nitric and muriatic acids.

5. Gallic acid and the infusion of nut-galls occasion no precipitate.

6. The oxalate of ammonia occasions a white precipitate, which is soluble in nitric and muriatic acids.

7. Arseniate of potash when dropped into solutions of salts of cerium occasions a white precipitate. Tartrate of potash occasions no precipitate.

1. Nitrate.

Sp. 1. *Nitrate of cerium.* Nitric acid unites with both the oxides of cerium. With the white oxide it combines most readily, especially when that oxide is in the state of a carbonate. The solution is colourless, crystallizes with difficulty, retains an excess of acid, and has an austere and sweet taste.

The red oxide dissolves with difficulty in cold nitric acid, but readily when the action of the acid is promoted by heat. The solution is yellow; and when it contains an excess of acid, it yields small white crystals, which deliquesce when exposed to the air. The saturated solution does not crystallize.

Both the nitrate and pernitrate of cerium are soluble in alcohol. Heat decomposes them, leaving a red-coloured oxide.*

2. Carbonate.

Sp. 2. *Carbonate of cerium.* Carbonic acid combines readily with the white oxide of cerium. The easiest way of forming the carbonate is to precipitate white oxide of cerium from its solution by means of an alkaline carbonate. The precipitate is granular, of a silvery whiteness, and insoluble in water acidulated with carbonic acid. According to the analysis of Klaproth, carbonate of cerium is composed of

23 acid
65 oxide
12 water

100

This salt may be formed by causing a current of carbonic acid gas to pass through water having the oxide of cerium suspended in it. So great indeed is the avidity of this oxide for carbonic acid that it absorbs it even from the air.†

Sp. 3. *Phosphate of cerium.* When a mixture of oxide of cerium and phosphoric acid is digested in water, a white insoluble powder is obtained, which is phosphate of cerium. The same powder is thrown down when the solutions of cerium are mixed with phosphate of soda. It is soluble in nitric and muriatic acids.‡

4. Sulphate.

Sp. 4. *Sulphate of cerium.* Sulphuric acid dissolves the red oxide of cerium with difficulty. By digesting the oxide in diluted acid for a sufficient length of time, a solution may be obtained. It is of an orange colour, and yields by evaporation small octahedral and needle-form crystals of persulphate of cerium. Their colour is partly lemon-yellow, partly orange. The salt thus obtained is not soluble in water, except by means of an excess of acid. Then its taste is acid and sweet. When the crystals are exposed to the air, they soon fall into a yellow powder.

Sulphuric acid combines very readily with the white oxide of cerium, especially when it is in the state of a carbonate. The solution is colourless, has a sweet taste, and readily yields crystals of sulphate of cerium. When persulphate of cerium

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* Hisinger and Berzelius, Gehlen's Jour. ii. 409. Vauquelin, Ann. de Chim. liv. 51.

† Klaproth, Hisinger and Berzelius, Vauquelin.

‡ Klaproth, Hisinger, Berzelius.

is treated with muriatic acid, chlorine gas is disengaged; the salt loses its colour, and is converted into sulphate of cerium. A moderate heat disengages oxygen, and produces the same change.*

Sp. 5. *Sulphate of potash-and-cerium.* When supersulphate or superpersulphate of cerium is decomposed by potash, a triple salt is deposited, white with the first, and yellow with the second salt. This triple salt melts when heated. Nitric acid dissolves and decomposes it. The same triple salt is deposited when muriate of cerium is poured into a solution of sulphate of potash.†

Sp. 6. *Sulphite of cerium.* Sulphurous acid dissolves the red oxide of cerium, and the solution yields by evaporation crystals of a pale amethyst colour.‡

Sp. 7. *Seleniate of cerium.* The *perseleniate* is a lemon-yellow powder, which allows its acid to escape when heat is applied. The *biperseleniate* is soluble, and yields when evaporated a pale yellow and transparent varnish.

The *protoseleniate* is a white powder which dissolves in selenic acid, and forms a soluble *biprotoseleniate.*§

8. Arseniate.

Sp. 8. *Arseniate of cerium.* Arsenic acid does not occasion a precipitate when dropped into muriate of cerium. When digested with oxide of cerium, an insoluble compound is obtained, which may be rendered soluble by adding an excess of acid. The solution does not crystallize; when evaporated, it deposites insoluble arseniate, and the residue dries into a gelatinous colourless mass.||

Sp. 9. *Molybdate of cerium.* Molybdate of ammonia occasions no precipitate in the supersalts of cerium; but from the neutral solutions it precipitates molybdate of cerium in the form of a white salt not soluble in acids.**

10. Acetate.

Sp. 10. *Acetate of cerium.* Acetic acid readily dissolves the oxide of cerium, newly precipitated by means of alkalies. The solution, when saturated, has a sweet taste, and yields by evaporation small granulated crystals; readily soluble in water, but sparingly soluble in alcohol, and not altered by exposure to the air.††

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* Klaproth, Hisinger and Berzelius, Vauquelin.

† Hisinger and Berzelius, Gehlen's Jour. ii. 413.

‡ Klaproth, Gehlen's Jour. ii. 312.

§ Berzelius; Ann. de Chim. et de Phys. ix. 267.

|| Hisinger and Berzelius, Gehlen's Jour. ii. 413.

** Ibid.

†† Ibid. ii. 414.

Sp. 11. *Benzoate of cerium.* Benzoic acid occasions no precipitate in muriate of cerium; but when it is digested on recently precipitated oxide of cerium, a solution takes place. On cooling, the liquid first lets fall crystals of benzoic acid, then the benzoate of cerium falls in the state of a white insoluble powder.*

12. Succinate.

Sp. 12. *Succinate of cerium.* When a few drops of succinate of ammonia are poured into muriate or nitrate of cerium, a precipitate is formed which soon disappears. When more of the re-agent is added, the succinate of cerium is separated in the state of a white powder. This salt is not wholly insoluble in water, as a small portion still remains in solution. Succinate of ammonia does not precipitate cerium from the acetate. This furnishes us with a ready means of separating iron from cerium when they happen to be mixed.†

Sp. 13. *Oxalate of cerium.* Oxalic acid and oxalate of ammonia precipitate cerium from its solutions. The precipitate, with the peroxide, is red; with the protoxide, white. An excess of acid does not redissolve it; but ammonia readily effects its solution, giving it a yellow colour.‡

14. Tartrate.

Sp. 14. *Tartrate of cerium.* When tartaric acid is digested upon recently precipitated oxide of cerium, it forms a salt readily soluble in water, in consequence of the excess of acid which it contains. When the solution is mixed with a great quantity of water, white insoluble flakes of tartrate of cerium are precipitated. Tartaric acid occasions no precipitate in the sulphate, nitrate, or muriate of cerium; but tartrate of potash throws down the tartrate of cerium in the state of a white powder. It is soft, light, tasteless, and insoluble in water. It is soluble in nitric, muriatic, and sulphuric acids, and in pure alkalies.§

Sp. 15. *Citrate of cerium.* Muriate of cerium is not precipitated by citric acid. By digesting the acid on recently precipitated oxide, an insoluble compound is formed, which is rendered soluble by an excess of acid. The solution does not crystallize. Alcohol deprives it of its water and of part of its acid, but does not dissolve it.‖

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* Hisinger and Berzelius, Gehlen's Jour. ii. 413.

† Ibid. ii. 414.

‡ Ibid. ii. 413.

§ Hisinger and Berzelius, Vauquelin.

‖ Hisinger and Berzelius, Gehlen's Jour. ii. 113.

SECT. XXII.

SALTS OF URANIUM.

Book II. Division II.

This genus of salts has been hitherto examined only by Klaproth, Richter, and Bucholz.* This last chemist has published a very particular description of the sulphate and nitrate of uranium.

The salts of uranium may be distinguished by the following properties:

Characters.

1. The greater number of them are soluble in water, and the solution has a yellow colour.

2. The pure alkalies occasion in these solutions a yellow precipitate; the alkaline carbonates a white precipitate, soluble in an excess of alkali.

3. Ferrochyazate of potash occasions a brownish-red precipitate, which does not assume the form of flakes like the ferrochyazate of copper.

4. Hydrosulphuret of potash occasions a brownish-yellow precipitate.

5. The infusion of nut-galls occasions a chocolate-coloured precipitate.

6. No precipitate is occasioned by zinc, iron, or tin.

1. Nitrate.

Sp. 1. *Nitrate of uranium.* Nitric acid readily dissolves uranium with the emission of nitrous gas. The solution has a yellowish colour.† The oxide of uranium is dissolved by this acid with still greater facility. From the trials of Bucholz‡ it follows, that the acid unites with the oxide in two proportions, forming a nitrate and subnitrate of uranium.

1. *Nitrate.* This salt is best formed, as Klaproth showed, by dissolving the oxide of uranium in nitric acid, and bringing the solution to crystallization. The best method of obtaining regular crystals is to expose the solution to a very moderate heat. When a saturated hot solution is cooled quickly, crystals likewise are obtained, but not so regular. The crystallization succeeds best when there is a slight excess of acid.§ The colour of the crystals varies somewhat according to the method of crystallizing. When the solution is fully saturated

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* Klaproth, Crell's Annals, i. 130. Eng. Trans. Richter's Neuern Gegenstande. Gren's Handbuck, iii. 741.

† Bucholz, Gehlen's Jour. iv. 36.

‡ Ibid. p. 158.

§ Ibid. p. 145.

with oxide, the crystals are of a lemon-yellow, and greenish at the edges; but when there is an excess of acid present, they have all a greenish colour. The crystals have the form of tables, often hexagonal; but by cautious management, they may be obtained in large four-sided rectangular flat prisms.*

Properties.

They are extremely soluble in water; 93 parts of that liquid at the common temperature being capable of dissolving 200 parts of nitrate of uranium. Boiling water dissolves any quantity; the water of crystallization being sufficient at that temperature to keep the salt in solution. They are still more soluble in pure alcohol; one part of that liquid dissolving $3\frac{1}{3}$d parts of the nitrate. The solution has a yellow colour, and is of the consistence of a syrup. Boiling alcohol dissolves any quantity, but a portion of the salt precipitates again as the solution cools. By evaporation the solution yields regular crystals of nitrate of uranium. If it be kept for a long time in the temperature of about 112°, the salt is partly decomposed, a yellow powder precipitating; a portion of which is oxide of uranium, and a portion of the same oxide united probably to a vegetable acid. When four parts of nitrate of uranium and one part of alcohol are distilled in a very moderate heat, the first portion which comes over has the smell of nitric ether; the second contains a portion of acetic acid.†

Sulphuric ether dissolves about one-fourth of its weight of this salt; the solution is lemon-yellow; but when exposed to the sun's rays, it becomes in a few minutes green, and in some hours a watery portion subsides, of a green colour, containing uranium. The ether acquires the smell of nitric ether, and a quantity of black oxide of uranium precipitates.‡

When nitrate of uranium is exposed to the air at the temperature of about 100°, it very soon falls into a white powder; but in cold and damp air it very soon deliquesces into a liquid.§

When heated, it undergoes the watery fusion; the water which it contains is gradually dissipated, carrying along with it a portion of the acid. If the heat be increased, nitrous gas makes its escape, and at last a portion of oxygen gas is disengaged. By this process, not only the whole of the acid and water is dissipated, but the metal loses also a considerable portion of its oxygen.||

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* Bucholz, Gehlen's Jour. iv. 116.

† Ibid. p. 151.

‡ Ibid. p. 156.

§ Ibid. p. 150.

|| Ibid. p. 149.

Composition.

From the experiments of Bucholz, it follows that this salt is composed of

61 oxide
25 acid
14 water

100*

2. *Subnitrate.* When nitrate of uranium is heated till its colour becomes orange-yellow, it does not dissolve completely in water, leaving behind a lemon-yellow powder. A portion of the same powder likewise precipitates from the solution before it can be brought to crystallize. This powder is insoluble in water, and has been shown by Bucholz to be a subnitrate of uranium.†

2. Sulphate.

Sp. 2. *Sulphate of uranium.* Sulphuric acid, whether concentrated or diluted, has but little effect upon uranium in the metallic state.‡ By boiling the oxide obtained from nitrate of uranium by means of heat, with a sufficient quantity of diluted sulphuric acid, and setting the solution aside in a warm place, Mr. Bucholz obtained needle-form crystals of sulphate of uranium. As these crystals contained an excess of acid, though a portion of the oxide remained undissolved, Bucholz re-dissolved them in water, added a little nitric acid, and boiled them to dryness over a new portion of oxide of uranium. The mass was dissolved again in water, filtered, and set aside. After some months very small prismatic crystals separated; and by continuing the evaporation some crystals were obtained in the shape of tables.

The colour of these crystals is lemon-yellow. They dissolve in $\frac{5}{8}$ths of their weight of cold water, and in $\frac{9}{20}$ths of their weight of that liquid when boiling hot. The solution has the consistency of a syrup, and gradually yields regular crystals when subjected to spontaneous evaporation. Pure alcohol at the common temperature of the air dissolves $\frac{1}{25}$th part, and boiling alcohol $\frac{1}{20}$th part of its weight of them. When the solution was exposed to the sun, its colour, at first light yellow, became green, and the whole of the oxide gradually precipitated, carrying along with it a portion of sulphuric acid. At the same time the smell of ether became perceptible in the liquid.

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* Bucholz, Gehlen's Jour. iv. 148.

† Ibid. p. 158.

‡ Ibid. p. 36.

When crystallized sulphate of uranium is exposed to a red heat, it loses 14 per cent. of its weight; but in a white heat it loses the whole of its acid and water. The residue, which weighs $\frac{46}{100}$ths of the original salt, is a greyish-black powder, consisting of pure oxide of uranium.

This salt, according to the experiments of Bucholz, to whom we are indebted for the whole of the facts above enumerated, is composed of

18	acid
70	oxide
12	water
100*	

Sp. 3. *Seleniate of uranium.* The neutral salt is a lemon-yellow powder, which when heated allows its acid with a portion of oxygen to escape, and leaves a green-coloured oxide. The *biseleniate* is formed by dissolving the preceding salt in selenic acid. When evaporated it leaves a pale yellow transparent varnish. When quite dry it is white, opaque, and crystalline.†

Remaining Species.

4. Phosphoric acid forms with oxide of uranium yellowish-white flakes, scarcely soluble in water. The salt may be precipitated by adding phosphoric acid to the acetate of uranium.‡ Phosphate.

5. When an alkaline arseniate is dropped into nitrate of uranium, the arseniate of uranium precipitates in the state of a yellowish-white powder. Arseniate.

6 and 7. The tungstate and molybdate of uranium may be obtained by a similar process. The first is a brownish-white powder, insoluble in water: the second is whitish-yellow, and difficultly soluble.

8. Concentrated acetic acid dissolves oxide of uranium by digestion, and yields beautiful yellow crystals in the form of long, slender, transparent, four-sided prisms terminated by four-sided pyramids. When heated gradually, the acid is decomposed and driven off, but the remaining oxide still retains the form of the crystals.§ Acetate.

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* Gehlen's Jour. iv. 134.

† Berzelius, Ann. de Chim. et de Phys. ix. 266.

‡ Klaproth, Crell's Annals, i. 135. Engl. Trans.

§ Ibid.

Tartrate.

9. Tartaric acid forms with the oxide of uranium a salt scarcely soluble in water.

Richter formed also the borate, oxalate, citrate, malate, benzoate, and succinate of uranium; but the properties of these salts have not been described.

SECT. XXIII.

SALTS OF ZINC.

Almost all the acids act with energy on zinc, in consequence of the strong affinity which it has for oxygen. The salts of zinc, therefore, are very easily formed; and as the metal forms only one oxide they are not liable to change their state, like the salts of iron and tin. They may be distinguished by the following properties:

Characters.

1. The greater number of them are soluble in water, and the solution is colourless and transparent.

2. Ferrochyazate of potash occasions a white gelatinous precipitate when dropped into these solutions.

3. Hydrosulphuret of potash and sulphuretted hydrogen gas occasion a white precipitate.

4. Gallic acid and the infusion of nutgalls occasion no precipitate when dropped into these solutions.

5. Alkalies occasion a white precipitate, which is readily dissolved by sulphuric or muriatic acid.

6. Zinc is not precipitated in the metallic form by any of the other metals.

7. Sulphochyazate of potash and hydriodate of potash occasion white precipitates when dropped into a solution of a salt of zinc.

1. Nitrate.

Sp. 1. *Nitrate of zinc.* Nitric acid attacks zinc with prodigious violence, and has been said even to inflame it. It is necessary to moderate its action by using it in a diluted state: even then considerable heat is evolved, and a strong effervescence is occasioned by the escape of nitrous oxide gas.

The solution is transparent and colourless, very caustic, and yields by evaporation flat striated tetrahedral prisms, terminated by four-sided pyramids. The specific gravity of these crystals is 2·096.* They attract moisture when exposed to the air. They are soluble both in water and alcohol. When

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* Hassenfratz, Ann. de Chim. xxviii. 12.

heated they melt and detonate on burning coals, emitting a red flame. When distilled, they emit red vapours of nitrous acid, and assume a gelatinous form. In a strong heat they are decomposed completely, giving out nitrous gas and oxygen gas.

2. Carbonate.

Sp. 2. *Carbonate of zinc.* Liquid carbonic acid, confined in a vessel with zinc, or its oxide reduced to the state of a fine powder, dissolves a considerable portion of it; and the solution, when exposed to the air, is gradually covered with an iridescent pellicle of oxide of zinc.[*] The carbonate of zinc may be obtained in the state of a white powder, by precipitating zinc from its solution in acids by means of an alkaline carbonate.

Bergman first ascertained by analysis that this salt occurs native under the name of *calamine;* but his inferences were disputed by mineralogists, and considered by most as erroneous. Yet they have been fully confirmed by the precise analysis of Mr. Smithson, who has demonstrated that different substances have been confounded under the name of calamine, and among others the carbonate of zinc.

According to the analysis of Bergman, native carbonate of zinc is composed of

Composition.

28 acid
66 oxide
6 water
———
100[†]

From the analysis of Mr. Smithson, it follows that *arid* carbonate is composed of

1 acid
2 oxide
———
3[‡]

When water is present, the proportion of the other constituents still continues the same. Mr. Smithson has shown, that the water in that case is combined with the oxide of zinc, constituting a hydrate, which is composed of

3 oxide
1 water
———
4[§]

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[*] Bergman, i. 35.

[†] Opusc. ii. 326.

[‡] Phil. Trans. 1803, p. 23.

[§] Phil. Trans. 1803, p. 23.

The anhydrous carbonate of zinc is composed of

Carbonic acid	34·92	1 atom
Oxide of zinc	65·08	1 atom
	100·00	

The constituents of the hydrous carbonate are 1 atom acid, 1 atom oxide, and 1 atom water, or by weight

Carbonic acid	30·55
Oxide of zinc	56·94
Water	12·51
	100·00

3. Borate.

Sp. 3. *Borate of zinc.* Boracic acid scarcely attacks zinc; but it combines with its oxide, and forms with it an insoluble *borate of zinc.* This salt may be precipitated in a white powder, by pouring borate of soda into the nitrate or muriate of zinc; or by mixing boracic acid with liquid sulphate of zinc. When strongly heated, this borate becomes yellow, and is at last converted into an opaque slag.*

4. Silicate.

Sp. 4. *Silicate of zinc.* This salt occurs native along with the ore of lead, and is known by the name of *electric calamine.* It is often crystallized in small six-sided prisms and acute octahedrons. Its colour is white with a shade of grey, blue, or yellow. Its fracture is foliated, it is somewhat transparent, and has a specific gravity of 3·4. If it be a compound of 1 atom silica, and 1 atom oxide of zinc, its constituents must be

Silica	28·08
Oxide of zinc	71·92
	100·00

Now the mean of the analyses of Klaproth and John gives us

Silica	29·7
Oxide	70·3
	100·0

Numbers which come sufficiently near to show us that the composition which we have supposed is the true one.

5. Phosphate.

Sp. 5. *Phosphate of zinc.* Phosphoric acid dissolves zinc

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* Wenzel's Verwandtschaft, p. 251.

with effervescence, but ceases to act when the quantity of zinc dissolved is sufficient to convert the acid into a biphosphate composed of two atoms acid, and 1 atom oxide of zinc. This solution does not crystallize, and when evaporated to dryness may be again re-dissolved in water, unless the heat has been sufficient to drive off the whole of the water, and fuse the salt into a glass, in which case it becomes insoluble. The taste of this biphosphate is acid and astringent, and it reddens vegetable blues.

When carbonate of zinc is introduced into phosphoric acid it is dissolved with effervescence, and a biphosphate of zinc formed as when the metal is employed. But if we boil the liquid over carbonate of zinc, after it refuses to take up any more in the cold, the whole is gradually converted into a tough magma which becomes very hard when cold. It softens when heated, and, if we urge the fire, abundance of nitrous gas is given out. The substance thus obtained is a phosphate of zinc. It is a tasteless white matter, insoluble in water. Before the blowpipe it readily melts into a transparent colourless glass. Phosphate of zinc is composed of

Phosphoric acid	100
Oxide of zinc	113·8

The biphosphate contains twice as much acid united to the same weight of base.

6. Sulphate.

Sp. 6. *Sulphate of zinc.* Concentrated sulphuric acid scarcely acts upon zinc without the assistance of heat; but if it be sufficiently diluted with water, it attracts the metal with force; hydrogen gas is emitted, and the zinc is very speedily dissolved. In this case the water is decomposed; its oxygen combines with the metal, while its hydrogen is exhaled. When the solution is sufficiently concentrated by evaporation, it yields the sulphate of zinc in crystals.

History.

This salt, according to the best accounts, was discovered at Ramelsberg, in Germany, about the middle of the 16th century. Many ascribe the invention to Julius Duke of Brunswick. Henkel and Neumann were the first chemists who proved that it contained zinc; and Brandt first ascertained its composition completely.* It is generally formed for commercial purposes from sulphuretted zinc, or blende, as it is called by mineralogists. This ore is roasted, which converts the

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* Beckman's History of Inventions, art. *Zinc.*

sulphur into an acid; it is then dissolved in water, and concentrated so much that, on cooling, it crystallizes very rapidly and forms a mass not unlike loaf-sugar. This salt is usually called *white vitriol.* It is almost always contaminated with iron, and often with copper and lead. Hence the yellow spots which are visible on it, and hence also the reason that its solution in water lets fall a dirty brown sediment; a circumstance very much complained of by surgeons when they use that solution in medicine. It may be easily purified by dissolving it in water, and putting into the solution a quantity of zinc filings; taking care to agitate it occasionally. The zinc precipitates the foreign metals, and takes their place. The solution is then to be filtered, and the sulphate of zinc may be obtained from it in crystals by proper evaporation.

Properties.

Its crystals are four-sided rectangular prisms, terminated by quadrangular pyramids, the faces of which make angles of 135° with the angles of the prism. Two opposite edges of the prism are commonly replaced by small faces, which renders the prisms six-sided.[*] Its specific gravity when crystallized is, by experiments, 1·980; when in the state in which it commonly occurs in commerce, it is 1·3275.[†] At the temperature of 60°, water dissolves 1·4 times its weight of it. Boiling water dissolves any quantity whatever. When heated, it melts and speedily loses its water of crystallization, and, in a high temperature, loses most part of its acid. The constituents of this salt are,

1 atom sulphuric acid ..... = 31·74
1 atom oxide of zinc ...... = 32·54
5 atoms water .... = 35·72
100·00

This very nearly agrees with the analysis of Berzelius, who found the constituents of this salt

Acid	30·965
Oxide	32·585
Water	36·450
	100·000[‡]

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[*] Bergman, ii. 327.

[†] Hassenfratz, Ann. de Chim. xxviii. 12. According to Dr. Watson, 1·933, (Essays, v. 67.)

[‡] Ann. de Chim. lxxx 120.

When this salt is strongly heated it loses the whole of its acid and water, and the oxide of zinc remains behind in a state of purity. Probably pure sulphuric acid might be easily obtained by distilling this salt. For it parts with the whole of its water before the acid begins to separate.

Sp. 7. *Sulphite of zinc.* Sulphurous acid dissolves the oxide of zinc with the evolution of heat, but without effervescence. The solution yields crystals of sulphite of zinc. These crystals have a less acrid, but more styptic taste than the following species. They are less soluble in water, and more easily crystallized. They are insoluble in alcohol. When exposed to the air, they are very soon changed into sulphate of zinc; whereas the sulphuretted sulphite remains long unchanged.

8. Hyposulphite.

Sp. 8. *Hyposulphite of zinc.* Sulphurous acid attacks zinc with considerable violence, heat is produced, and sulphuretted hydrogen gas is exhaled. The solution has an acrid, astringent, sulphureous taste. When exposed to the air, it becomes thick like honey, and deposits long slender crystals in the form of four-sided prisms, terminated by four-sided pyramids. These are crystals of *hyposulphite of zinc*, as Fourcroy and Vauquelin have proved. They are soluble in water and in alcohol. When exposed to the air they become white, and deposit a white insoluble powder. Before the blowpipe the salt swells, emits a brilliant light, and forms dendritical ramifications. When distilled, it yields water, sulphurous acid, sulphuric acid, and sulphur; and there remain behind oxide of zinc and a little sulphate of that metal. Sulphuric, nitric, and muriatic acids, when poured into its solution in water, drive off the sulphurous acid, while a quantity of sulphur precipitates. The theory of the formation of this salt is obvious. During the solution of the zinc, both water and sulphurous acid are decomposed. Hence the reason of the sulphuretted hydrogen gas exhaled. But the greatest portion of the acid gives out half its oxygen to oxydize the zinc. It is thus changed into hyposulphurous acid, which unites with the oxide of zinc formed.

When a mixture of sulphur and white oxide of zinc is treated with sulphurous acid, the product is a hyposulphite.*

Sp. 9. *Seleniate of zinc.* The neutral salt is a crystalline powder insoluble in water. When heated it gives out its water of combination. It then melts and becomes yellow and

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* Fourcroy, v. 380.

transparent. But on cooling it resumes its white colour. Its surface and fracture are crystalline. At a white heat it lets a portion of its acid escape, and is converted into a subseleniate which undergoes no farther alteration from the fire.

The biseleniate is very soluble in water; when evaporated, it leaves a transparent matter like gum.[*]

10. Arseniate.

Sp. 10. *Arseniate of zinc.* When arsenic acid is poured upon zinc, an effervescence ensues, arsenical hydrogen gas is emitted, and a black powder precipitates, which is arsenic in the metallic state. Hence we see that the zinc deprives both a portion of water and of arsenic acid of their oxygen. When one part of zinc filings and two parts of dry arsenic acid are distilled in a retort, a violent detonation takes place when the retort becomes red, occasioned by the sudden absorption of the oxygen of the acid by the zinc. The arseniate of zinc may be precipitated by pouring arsenic acid into the acetate of zinc, or by mixing the solution of the alkaline arseniates with the sulphate of zinc. It is a white powder, insoluble in water.[†]

Sp. 11. *Antimoniate of zinc.* This salt is obtained when antimoniate of potash is dropped into a solution of sulphate of zinc. It is a white powder having a crystalline appearance when dried. It is soluble to a certain degree in water. When heated it gives out its water of crystallization and becomes yellow. It is not reduced by the blowpipe upon charcoal.[‡]

Sp. 12, 13, 14. By the same process may the tungstate, molybdate, and chromate of zinc be obtained. They also are insoluble in water: the two first are white, the last of an orange-red colour.

15. Acetate.

Sp. 15. *Acetate of zinc.* Acetic acid readily dissolves zinc, and yields by evaporation crystals of acetate of zinc, which were first mentioned by Glauber. This salt has a bitter metallic taste. Its crystals are rhomboidal or hexagonal plates, of a talky appearance. It is not altered by exposure to the air; it is very soluble in water. When thrown upon live coals, it burns with a blue flame. When distilled, it yields water, an inflammable liquid, and some oil, and towards the end of the process oxide of zinc sublimes.[§]

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[*] Berzelius, Ann. de Chim. et de Phys. ix. 265.

[†] Scheele, i. 181.

[‡] Berzelius, Nicholson's Journal, xxxv. 42.

[§] Monnet.

This salt has been lately recommended by Dr. Henry as an excellent application in cases of inflammation.

Sp. 16. *Succinate of zinc.* Succinic acid dissolves zinc with effervescence; and the solution yields long slender foliated crystals, the properties of which have not been examined.*

Sp. 17. *Benzoate of zinc.* Zinc is readily dissolved by benzoic acid. The solution yields needle-shaped crystals, which are soluble in water and alcohol. When exposed to heat, their acid is volatilized.†

18. Oxalate.

Sp. 18. *Oxalate of zinc.* Oxalic acid attacks zinc with a violent effervescence, and a white powder soon subsides, which is oxalate of zinc. The same salt is precipitated when oxalic acid is dropped into the solution of sulphate, nitrate, or muriate of zinc. It contains 75 per cent. of metal. This salt is scarcely soluble in water, unless there be an excess of acid.‡

Sp. 19. *Tartrate of zinc.* Tartaric acid attacks zinc with effervescence, and forms with it a salt difficultly soluble in water, the properties of which have not been examined.§

20. Citrate.

Sp. 20. *Citrate of zinc.* Citric acid attacks zinc with effervescence, and gradually deposits small brilliant crystals of citrate of zinc. They are insoluble in water, and have a styptic and metallic taste. They are composed of

59 acid
41 oxide
—–
100

21. Malate.

Sp. 21. *Malate of zinc.* Malic acid dissolves zinc, and yields by evaporation beautiful crystals of malate of zinc.||

Sp. 22. *Lactate of zinc.* Lactic acid dissolves zinc with effervescence, and the salt formed is capable of crystallizing.** The crystals have the figure of four-sided prisms, terminated by oblique summits. At the temperature of 70° they dissolve in 50 times their weight of water, and they are more soluble in boiling water.††

Sp. 23. *Tartrate of potash-and-zinc.* This salt may be formed by boiling together tartar and zinc filings and water. It is very soluble in water, and not easily crystallized. No

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* Wenzel's Verwandtschaft, p. 240.

† Trommsdorf, Ann. de Chim. xi. 317.

‡ Bergman, i. 271.

§ Dijon Academicians.

|| Scheele, Crell's Annals, ii. 10. Eng. Trans.

** Scheele, ii. 65.

†† Braconnot, Ann. de Chim. lxxxvi. 91.

precipitation is produced in its solution by the alkalies or their carbonates.[*]

Sp. 24. *Sulphate of zinc-and-iron.* This salt may be obtained by mixing together the solutions of sulphate of iron and of zinc, or by dissolving iron and zinc together in diluted sulphuric acid. It crystallizes in rhomboids which have nearly the figure of sulphate of zinc, but its colour is a pale green. Its taste and solubility are nearly the same as those of sulphate of zinc. It contains a much greater proportion of zinc than iron.

Sp. 25. *Sulphate of zinc-and-cobalt.* This salt, first pointed out by Link, may be obtained by digesting zafre in sulphate of zinc. Large four-sided prisms are obtained by evaporation, which effloresce when exposed to the air.[†]

The only one of the salts of zinc, much employed in the arts, is the sulphate. The acetate is sometimes used as an external application in cases of inflammation. The composition of the salts of zinc is easily determined by considering them as compounds of 1 atom oxide of zinc, and 1 atom of each of the acids. An atom of oxide of zinc weighs 5·125, and the weight of an atom of each of the acids has been given in a preceding chapter of this volume.

SECT. XXIV.

SALTS OF CADMIUM.

General characters.

This genus of salts, as far as it has been hitherto examined, may be distinguished by the following characters.

1. A considerable number of them are soluble in water. The aqueous solutions are colourless, or have a very slight yellow shade. The insoluble salts of cadmium are white powders.

2. When a fixed alkali is dropped into a solution of cadmium, the oxide is precipitated in the state of a white hydrate, and is not again redissolved by adding an excess of the precipitant.

3. Ammonia likewise precipitates it in the state of a white hydrate. The precipitate is again redissolved, when an excess of ammonia is added.

4. The alkaline carbonates throw down cadmium in the state of a white carbonate. This carbonate does not form a

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[*] Dijon Academicians; and Thenard, Ann. de Chim. xxxviii. 35.

[†] Crell's Annals, 1796. i. 32.

hydrate, as is the case with the carbonate of zinc. Neither is it redissolved by the addition of an excess of carbonate of ammonia, as is the case with the carbonate of zinc, unless there existed a notable excess of acid in the solution before the addition of the carbonate of ammonia.

5. Phosphate of soda throws down cadmium in the state of a white powder; while zinc is thrown down by the same precipitant in the state of crystalline scales.

6. Sulphuretted hydrogen gas, and the hydrosulphurets precipitate cadmium yellow or orange. This precipitate resembles orpiment; but may be distinguished by the facility with which it dissolves in muriatic acid, and by its bearing a red heat without being altered.

7. Ferrochyazate of potash throws down cadmium from its solutions *white*.

8. Infusion of nutgalls does not occasion any precipitate.

9. A plate of zinc, when put into a solution of cadmium, throws down that metal in a reguline state in dendritical leaves.

1. Nitrate.

Sp. 1. *Nitrate of cadmium.* This salt crystallizes in prisms or needles, adhering together, and constituting a radiated mass. When exposed to the air it speedily deliquesces into a liquid. Its composition, according to the analysis of Stromeyer, is as follows:

Nitric acid	35·7838	35·064
Oxide of cadmium	42·1526	41·558
Water	22·0636	23·378
	100·0000	100·000*

Sp. 2. *Carbonate of cadmium.* It is a white powder, insoluble in water, and when heated to redness is very easily deprived of its carbonic acid. Its constituents, according to Stromeyer, are

Carbonic acid	25·453
Oxide of cadmium	74·547
	100·000

Sp. 3. *Borate of cadmium.* This salt is a white powder scarcely soluble in water, and after having been exposed to a red heat its constituents, according to Stromeyer, are

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* Theoretical composition, supposing the salt to consist of 1 atom acid + 1 atom oxide + 4 atoms water.

Boracic acid	27·8847
Oxide of cadmium	72·1153
	100·0000

4. Phosphate.

Sp. 4. *Phosphate of cadmium.* This salt is a white powder, insoluble in water, and when exposed to an incipient white, heat fuses into a transparent glass. According to Stromeyer, its constituents are

Phosphoric acid	30·7162
Oxide of cadmium	69·2838
	100·0000

5. Sulphate.

Sp. 5. *Sulphate of cadmium.* This salt crystallizes in large transparent rectangular prisms, very similar in appearance to sulphate of zinc, and very soluble in water. It effloresces strongly when exposed to the air, and is deprived of its water of crystallization by the application of a low heat; without undergoing previous liquefaction, as is the case with sulphate of zinc. It is not easily decomposed by the fire, and bears a low red heat without undergoing any change. In a strong red heat sulphuric acid is given out, and it is changed into a subsulphate which crystallizes in plates, and is difficultly soluble in water. The constituents of sulphate of cadmium, according to Stromeyer's analysis, are

Sulphuric acid	28·5230
Oxide of cadmium	45·9564
Water	25·5206
	100·0000

6. Acetate.

Sp. 6. *Acetate of cadmium.* It crystallizes in small prisms, usually adhering to each other in the form of a star. These crystals are little altered by exposure to the air, and are easily soluble in water.

Sp. 7. *Oxalate of cadmium* is a white powder which does not dissolve in water.

Sp. 8. *Tartrate of cadmium* crystallizes in small needles, adhering to each other, and scarcely soluble in water.

Sp. 9. *Citrate of cadmium* forms a white crystalline powder, which is scarcely taken up by water.*

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* All the facts contained in this section were ascertained by Stromeyer. See Gilbert's Annalen, lx. 193.

SECT. XXV.

SALTS OF LEAD.

Chap. II.

The salts of lead were formerly distinguished by the name of *saturn*, the title by which lead was known among the alchymists. The protoxide only of this metal seems capable of combining with acids so as to form salts. These bodies may be distinguished by the following properties:

Characters.

1. A considerable number of them are scarcely soluble in water without an excess of acid. These before the blow-pipe yield very readily a button of lead.

2. The solution of the soluble salts of lead in water is generally colourless and transparent.

3. They have almost all less or more of a sweet taste, accompanied with a certain degree of astringency.

4. Ferrochyazate of potash occasions a white precipitate when poured into solutions containing salts of lead.

5. Hydrosulphuret of potash occasions a black precipitate. The same precipitate is produced by sulphuretted hydrogen.

6. Gallic acid and the infusion of nut-galls occasion a white precipitate.

7. A plate of zinc kept in a solution of lead occasions either a white precipitate, or the lead appears in its metallic state.

1. Nitrate.

Sp. 1. *Nitrate of lead.* Nitric acid acts upon lead with considerable energy, provided it be not too much concentrated; first converting it into a white powder, which is a subnitrate, and then dissolving it, especially when assisted by heat. The yellow oxide of lead is dissolved by nitric acid completely, and without effervescence; but the red oxide is rendered white; $\frac{6}{7}$ths of its weight are dissolved, and $\frac{1}{7}$th is converted into brown oxide, and remains undissolved.[*] Hence we see that it is the yellow oxide of lead only which combines with nitric acid. Six-sevenths of the red oxide are decomposed; the excess of oxygen combines with the remaining seventh, and converts it into brown oxide, while the base or yellow oxide combines with the acid. Thus we see that nitric acid does not combine with the red or brown oxide of lead, but it combines with the protoxide or yellow oxide, and forms with it two salts, which we shall distinguish, as usual, by the names of *nitrate* and *subnitrate* of lead.

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[*] Proust.

1. *Nitrate of lead.* This salt is always formed when lead is dissolved in nitric acid, unless there be present an excess of lead, and a strong heat be applied. It is formed also by dissolving the carbonate or white lead in nitric acid. The solution is transparent and colourless, and when sufficiently concentrated by evaporation, crystallizes on cooling. The crystals are usually tetrahedrons, having their apex truncated, and sometimes six-sided pyramids, according to Rouelle. They are opaque and white, and have a silvery lustre. Their taste is sweetish and harsh. They are not altered by exposure to the air. They are soluble in 7·6 parts of boiling water.* Their specific gravity is 4·068.† When heated, they decrepitate, and then undergo a kind of detonation, emitting very brilliant sparks.‡ When they are triturated with sulphur in a hot mortar, a feeble detonation is produced, and the lead is reduced to the metallic state.§

Composition. The constituents of this salt, according to the best analyses hitherto made, are as follows:

	‖	**	††	‡‡
Acid....	32·7775	.. 33	.. 34	.. 32·53
Base....	67·2225	.. 67	.. 66	.. 67·47
	100·0000	100	100	100·00

The oxide of lead is thrown down by alkalies in the state of a yellow powder. Sulphuric, sulphurous, and muriatic acids combine with the oxide, and precipitate it in the state of a white powder. Iron occasions no precipitate though kept in the solution of nitrate of lead.§§

2. *Subnitrate.* This salt was obtained by Chevreul by boiling a mixture of equal weights of nitrate of lead and protoxide of lead, filtrating the liquid while hot, and allowing it to crystallize in close vessels. On cooling it deposited crystals in pearl-coloured scales. The taste of this salt is sweet and astringent. When a current of carbonic acid gas is passed

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* Wenzel's Verwandtschaft, p. 310.

† Hassenfratz, Ann. de Chim. xxviii. 12. By my trials 3·954.

‡ Bergman, ii. 470.

§ Van Mons, Ann. de Chim. xxvii. 81.

‖ Berzelius, Gilbert's Annalen, xl. 166.

** Chevreul, Ann. de Chim. lxxxiii. 69.

†† By my analysis.

‡‡ Theoretical composition.

§§ Wenzel's Verwandtschaft, p. 90.

through its solution, it is converted into common nitrate and carbonate of lead. Berzelius obtained this salt by precipitating nitrate of lead by means of a quantity of ammonia, not sufficient to saturate the whole of the nitric acid. The precipitate thus obtained was well washed and dried.* There can be no doubt from the analyses of Berzelius and Chevreul, that this salt contains just double the quantity of base that exists in the nitrate. The nitrate is composed of

Acid	100
Base	207·4

The constituents of the subnitrate are

	Berzelius.	Chevreul.
Acid	100	100
Base	412·8	403

2. Nitrite.

Sp. 2. *Nitrite of lead.* This salt was discovered by Proust; but its true composition was first ascertained by Berzelius† and Chevreul.‡ Wenzel had indeed obtained it, but at the time when his experiments were made it was impossible to draw the proper inference.§ It would appear from the experiments of Berzelius and Chevreul, that there are three subspecies of this salt, the *nitrite*, *subnitrite*, and *quadrosubnitrite.* The first composed of 1 atom acid + 1 atom base, the second of 1 atom acid + 2 atoms base, and the third of 1 atom acid + 4 atoms base.

(1.) *Subnitrite.* When a solution of nitrate of lead is boiled upon lead in the metallic state, the lead is gradually dissolved being oxydized at the expense of the acid, which partly flies off in the state of nitrous gas, and is partly converted into nitrous acid. If the requisite portion of lead only is dissolved, which, according to the experiments of Berzelius, amounts to 7·8 parts of lead for every 10 parts of nitrate of lead employed, the solution has a yellow colour and deposites subnitrite of lead in scales. But if a greater quantity of lead has been dissolved quadrosubnitrite is likewise formed, and almost the whole is converted into this salt when as much lead as possible is dissolved by boiling a solution of nitrate of lead on it. According to Chevreul the best way of obtaining subnitrite is to cause a current of carbonic acid gas to pass through a solution of quadrosubnitrite. One half of the oxide of lead is thrown down

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* Ann. de Chim. lxxxii. 242.

† Ibid. lxxxiii. 5.

‡ Ibid. 67.

§ Verwandtschaft, p. 90.

in the state of carbonate. The liquid which now contains only subnitrite, being filtered and evaporated, deposites crystals of the salt.

This salt crystallizes in plates or scales and has a yellow colour. 100 parts of water at the temperature of 74° dissolve 1·26 of this salt; 100 parts of boiling water dissolve 9·41 parts. When this solution is allowed to cool it retains more of the salt than cold water would be able to dissolve. This solution has a yellow colour. It restores the blue colour of litmus paper reddened by an acid. It does not absorb oxygen from the atmosphere; but when exposed to the air it becomes covered with a pellicle of carbonate of lead. When this salt in powder is thrown into nitric acid or acetic acid, nitrous fumes are disengaged. When a current of carbonic acid is passed through the solution of this salt in water, it would appear from Chevreul's experiments that one half of the oxide of lead is thrown down in the state of carbonate. The other half remaining, combined with the nitrous acid, constitutes *nitrite of lead.* But as he did not evaporate the solution, or obtain the nitrite in a separate state, we are ignorant of its properties.

When carbonate of potash is dropped into subnitrite of lead, a double decomposition takes place, carbonate of lead is precipitated and nitrite of potash remains in solution. When it is boiled with protoxide of lead the subnitrite of lead is converted into quadrosubnitrite; but a very long ebullition is requisite to complete this change. This subnitrite, according to the experiments of Berzelius and Chevreul which agree, is composed of

20	acid and water
80	protoxide of lead
100	

According to Chevreul* its constituents, abstracting the water, are

Acid	18·15	100
Base	81·85	450

If it be a compound of 1 atom nitrous acid and 2 atoms protoxide of lead, as it ought to be, its constituents should be

Acid	100
Base	486·95

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* Ann. de Chim. lxxviii. 88.

(2.) *Quadrosubnitrite.* This salt is obtained by dissolving a maximum of lead in nitrate of lead. It crystallizes in small needles united to each other in the form of stars. Its colour is brick red. 100 parts of boiling water dissolve about 3 parts of it, and 100 parts of water at the temperature of 74° dissolve about 0·7 of a part. It is decomposed by carbonate of potash and by sulphuric, nitric, and acetic acids in the same way as the preceding subspecies. Carbonic acid precipitates abundance of carbonate of lead. Its constituents, according to Berzelius, are

Acid	10·175	100
Oxide	89·825	882·8
	100·000	

According to Chevreul,

Acid	9·9	100
Oxide	90·1	910
	100·0	

If we suppose it a compound of 1 atom acid + 4 atoms oxide, its constituents ought to be

Acid	100
Oxide	973·9

(3.) *Nitrite.* Berzelius obtained this salt by mixing the solution of subnitrite with a quantity of sulphuric acid, just capable of saturating the half of the oxide of lead which it contained. The sulphate of lead formed being separated by the filter, the liquid was allowed to crystallize spontaneously. Octahedral crystals of a deep yellow colour were deposited. It is much more soluble in water than nitrate of lead. When heated it melts and swells much while its acid and water are escaping. According to the experiments and calculations of Berzelius its constituents are

Nitrous acid	23·925	100
Protoxide of lead	70·375	294·14
Water	5·700	
	100·000*	

Supposing it a compound of 1 atom hyponitrous acid and 1 atom oxide of lead, its composition ought to be

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* Ann. de Chim. lxxxiii. 23.

Acid	100
Oxide	294·73

3. Carbonate.

Sp. 3. *Carbonate of lead.* Carbonic acid has no action whatever on lead, neither is it capable of dissolving its oxide; but it combines readily with the yellow oxide, and forms a carbonate. This salt is most easily obtained by precipitating lead from its solution in nitric acid by the alkaline carbonates. By that process it is obtained in the state of a white powder. It is tasteless and insoluble in water; but soluble in pure potash, in the same manner as the oxides of lead.

White lead.

The *white lead* of commerce (or *ceruse*), employed as a paint, is merely a carbonate of lead, as Bergman first observed.* It is prepared by exposing thin plates of lead to the hot vapours of acetic acid. The metal is gradually corroded and converted into a carbonate, probably at the expense of the acid. The beauty of the colour depends principally on the purity of the lead employed.†

This salt occurs native. In that state it is usually white, and has a good deal of lustre. Its specific gravity is 7·2357.‡ It is sometimes crystallized in six-sided prisms, terminated by six-sided pyramids, sometimes in regular octahedrons,§ and sometimes in tables.‖ It is insoluble in water. When exposed to the action of the blow-pipe upon charcoal, the lead is immediately reduced to the metallic state.

This salt has been analyzed by some of the most expert chemists. The constituents, as determined by their experiments, may be seen in the following table:

Composition.

	**	††	‡‡	§§	‖‖	***
Acid	15	16	16·15	16·33	16·5	16·41
Yellow oxide ..	85	84	83·85	83·67	83·5	83·59
	100	100	100·00	100·00	100·0	100·00

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* Opusc. i. 39. Proust has lately shown the same thing. Jour. de Phys. lvi. 207. Scheele found that a little acetic acid was always separated from it when white lead was distilled with sulphuric acid. Crell's Annals, iii. 8. Eng. Trans.

† The best English white lead is made at Newcastle-upon-Tyne. An account of the German process will be found in the Ann. de Chim. lxxii. 225.

‡ Bournon, Nicholson's Jour. iv. 220.

§ Haüy, Jour. de Min. An. v. 502.

‖ As at Leadhills in Scotland.

** Chenevix, Nicholson's Quarto Jour. iv. 221.

†† Bergman, Opusc. ii. 393.

‡‡ Proust, Jour. de Phys. lvi. 207.

§§ Klaproth, Beitrage, iii. 165.

‖‖ Berzelius, Ann. de Chim. lxxvii. 83.

*** Theoretical composition.

4. Borate.

Sp. 4. *Borate of lead.* Boracic acid has no action on lead; but borate of lead is precipitated in the state of a white powder when borate of soda is mixed with nitrate of lead. Before the blow-pipe it melts into a colourless glass.* When one part of boracic acid is melted with two parts of red oxide of lead, the product, according to Reuss, is a greenish-yellow, transparent, hard, insoluble glass.†

5. Phosphate.

Sp. 5. *Phosphate of lead.* Phosphoric acid has but little action on lead; but when the two substances are left long in contact, the metal is corroded and some phosphate of lead formed. Three subspecies of this salt are known to exist.

1. *Neutral phosphate.* This salt exists native. It may be obtained by pouring a solution of muriate of lead in boiling water into phosphate of soda. A white powder falls down, which when properly washed and dried is pure phosphate. This salt is insoluble in water unless there be a considerable excess of acid; but it is soluble in pure soda, and probably forms with it a triple salt.‡ It dissolves readily in nitric acid, and likewise in concentrated muriatic acid when the action of the liquid is assisted by heat. As the solution cools, crystals of muriate of lead precipitate in abundance. Sulphuric acid, when assisted by heat, decomposes this salt, combining with the oxide, and leaving the acid in a state capable of dissolving in water. When heated, it melts, and assumes on cooling a regular polyhedral form. In a red heat it is decomposed by charcoal, which absorbs the oxygen from both of its component parts. The constituents of this salt are as follows:

	§	‖	**
Phosphoric acid	100	100	100
Protoxide of lead	300	314	311·1

2. *Superphosphate.* When a boiling solution of muriate of lead is poured into biphosphate of soda a precipitate falls, which after being well washed retains the property of reddening vegetable blues. According to the analysis of Berzelius,†† this salt is composed of

Phosphoric acid	100
Protoxide of lead	230·6

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* Wenzel's Verwandt, p. 252.

† Reuss de Sale Sedativo.

‡ Vauquelin, Jour. de Min. No. ix. p. 6.

§ By my analysis.

‖ Berzelius, Ann. de Chim. et Phys. ii. 160.

** Theoretical composition.

†† Ann. de Chim. et Phys. ii. 160.

3. *Subphosphate.* Berzelius obtained this subspecies by digesting phosphate of lead in caustic ammonia. The insoluble portion after being washed and dried was composed of

Phosphoric acid	100
Protoxide of lead	472

Here the oxide is $1\frac{1}{2}$ times as great as in the neutral phosphate. For $314 \times 1\frac{1}{2} = 471$.

Sp. 6. *Nitrophosphate of lead.* When phosphoric acid is poured into nitrate of lead small crystals are deposited at an interval of some hours. These crystals are a triple salt composed of 1 atom of nitrate of lead united to 2 atoms of phosphate of lead. They are but weakly acted on by water which is scarcely capable of removing the whole of the nitrate of lead.*

7. Phosphite.

Sp. 7. *Phosphite of lead.* Berzelius prepared this salt by pouring hot muriate of lead into phosphite of ammonia. The precipitate, being well boiled in water and dried, is pure phosphite of lead. It is a white powder tasteless and insoluble in water. When heated it gives out phosphorus and phosphuretted hydrogen gas. According to the analysis of Berzelius this salt is composed of

Phosphorous acid	19·78
Protoxide of lead	80·22
	100·00†

Berzelius found 3·15 per cent. of water; but it is obvious that this water must have been merely mechanically mixed, as it did not amount to much more than half an atom.

8. Sulphate.

Sp. 8. *Sulphate of lead.* Sulphuric acid does not attack lead while cold; but at a boiling heat it communicates a portion of its oxygen, sulphurous acid gas is emitted, and the whole is converted into a thick white mass, which is sulphate of lead. It may be obtained readily by pouring sulphuric acid into acetate of lead, or by mixing this last salt with any of the alkaline sulphates. The sulphate of lead precipitates in the state of a white powder. This salt is tasteless. Its specific gravity is 1·8742.‡ It is insoluble in alcohol and in nitric acid. According to Kirwan, it requires 1200 parts of water to dissolve

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* Berzelius, Ann. de Chim. et Phys. ii. 161.

† Ann. de Chim. et Phys. ii. 230.

‡ Hassenfratz, Ann. de Chim. xxviii. 12.

Chap. II.

it;[*] but when it contains an excess of acid, it is more soluble, and yields by evaporation small white crystals, which, according to Sage, have the form of tetrahedral prisms. It dissolves in strong muriatic acid when the action of the solvent is promoted by heat; the solution, on cooling, deposites many crystals of muriate of lead.[†] It is found native crystallized, according to Kirwan, in four-sided oblique-angled prisms;[‡] according to Haüy, in regular octahedrons.[§] The native sulphate of lead found in Paris mountain, Anglesey, is crystallized in four-sided pyramids; the specimens found at Leadhills in Scotland, are in transparent tables.

According to the most accurate analyses hitherto made, the constituents of this salt are as follows:

Composition.

	[‖]	[**]	[††]	[‡‡]	[§§]
Acid	23·37	24·72	26·5	26·32	26·316
Yellow oxide	75·00	75·28	73·5	73·68	73·684
Water	1·63				
	100·00	100·00	100·0	100·00	100·00

A hundred parts of this salt, according to Kirwan, contain 71 parts of pure lead.[‖‖]

In close vessels this salt endures a considerable heat without alteration. I find that, after being dried in the temperature of about 400°, it may be heated to redness in a platinum crucible without losing any weight. On charcoal it melts, and the lead is quickly reduced.

When this salt is treated with alkalies, it is deprived of the greater part of its acid; but a portion still adheres. The white powder obtained by this process is therefore a subsulphate of lead.

9. Sulphite.

Sp. 9. *Sulphite of lead.* Sulphurous acid has no action whatever on lead. It absorbs oxygen from the red oxide of that metal, and is converted into sulphuric acid. But it combines with the protoxide of lead, and forms with it a sulphite, which is in the state of a white powder, insoluble in water, and

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[*] Mineralogy, ii. 211.

[†] Descotils, Nicholson's Jour. xii. 221.

[‡] Kirwan's Min. ii. 211.

[§] Jour. de Min. An. v. p. 508.

[‖] Kirwan on Mineral Waters, Table IV.

[**] Bucholz, Gehlen's Journal, v. 262.

[††] Klaproth's Beitrage, iii. 166.

[‡‡] Berzelius, Ann. de Chim. lxxviii. 83.

[§§] Theoretical composition.

[‖‖] On Mineral Waters, Table IV. If the salt be free from water, 100 parts of it really contain exactly 68·421 parts of lead.

tasteless. Before the blow-pipe on charcoal it melts, becomes yellow, and the lead is at last reduced.* Sulphite of lead, dried in a temperature of about 300°, is composed of

Composition.

Sulphurous acid	22·2
Protoxide of lead	77·8
	100·0

When exposed to a red heat, it loses 5 per cent. of its weight; sulphurous acid exhales; and there remains a blackish mass composed of sulphate of lead and sulphuret. When treated with nitric acid, the sulphuret is decomposed, and crystals of nitrate obtained.

Sp. 10. *Hyposulphite of lead.* This salt is obtained by pouring nitrate of lead into the solution of any hyposulphite. A white precipitate falls which is at first redissolved; but upon adding the requisite quantity of nitrate it becomes permanent. This hyposulphite is a white mealy powder, which leaves an impression of sweetness when held long in the mouth. At a heat under 212° it turns black, and when the heat is raised it takes fire, becoming red hot, and burns with a weak flame. If it be now removed from the fire, the ignition and combustion may be maintained for any length of time by cautiously adding small quantities of the substance. When heated in a retort it loses 20 per cent. of its weight, which is pure sulphurous acid gas. When fully ignited the loss is 20·6 per cent. the residuum, which is a black powder, is, according to Mr. Herschell, a sulphuretted oxide of lead. The constituents of hyposulphite of lead, according to the analysis of Mr. Herschell, are as follows:

Hyposulphurous acid	29·7
Oxide of lead	70·3
	100·0

It is therefore a binhyposulphite of lead.†

Sp. 11. *Seleniate of lead.* This salt has the form of a heavy white powder, which falls very rapidly, and which is not soluble in an excess of acid. When heated it melts and becomes transparent and yellow. On cooling it recovers its white co-

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* Fourcroy and Vauquelin, Connoissances Chimiques, vi. 86.

† Edin. Phil. Jour. i. 24.

lour, becomes opaque, and exhibits a crystalline texture. In a heat nearly white it boils, and selenic acid sublimes, and there remains a subseleniate which is semitransparent and friable, and has a strongly marked crystalline texture. The seleniate of lead, according to the analysis of Berzelius, is composed of

Composition.

Selenic acid	1
Oxide of lead	2
	3 *

12. Arseniate.

Sp. 12. *Arseniate of lead.* Arsenic acid attacks lead in a digesting heat, communicates a portion of its oxygen, and converts it into arseniate of lead in the state of an insoluble white powder. When arsenic acid is poured into the solution of lead in nitric, muriatic, or arsenic acids, arseniate of lead precipitates in powder. When this salt is heated it melts; and if charcoal be thrown into the mass while in fusion, arsenic is volatilized, and the lead is reduced; the charcoal abstracting the oxygen from both of the component parts of the salt.

Arseniate of lead is completely insoluble in water. It has been found native. According to the analysis of Chenevix and Thenard, its constituents are as follows:

Composition.

	†	‡	§
Acid	33	35·7	34·12
Yellow oxide ..	63	64·3	65·88
Water	4		
	100	100·0	100·00

Sp. 13. *Antimoniate of lead.* This salt is obtained by pouring antimoniate of potash into nitrate of lead. It precipitates in the state of a white matter very similar in appearance to chloride of lead. It is quite insoluble in water. Before the blow-pipe on charcoal it is reduced to the metallic state, constituting an alloy of antimony and lead. Nitric acid does not decompose it completely; so that Berzelius, to whom we are indebted for every thing known respecting the antimoniates, was unable to analyze it. ‖

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* Ann. de Chim. et de Phys. ix. 339.

† Chenevix, Phil. Trans. 1801, p. 199.

‡ Thenard, Ann. de Chim. l. 123.

§ Theoretical composition.

‖ Nicholson's Journal, xxxv. 41.

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Sp. 14. *Antimonite of lead.* This salt may be obtained by the same process as the preceding, which it perfectly resembles in its properties.[*]

15. Chromate.

Sp. 15. *Chromate of lead.* This salt may be formed by mixing together the solutions of nitrate of lead and an alkaline chromate. The chromate of lead, in that case, precipitates in the state of an orange powder; but it exists native, and is indeed the compound from which chromic acid is usually obtained.

Its colour is red with a shade of yellow; and its crystals are four-sided prisms, sometimes terminated by four-sided pyramids. Its specific gravity is about 6. It is insoluble in water, but soluble in the fixed alkalies without decomposition. Nitric acid also dissolves it; but muriatic and sulphuric acids decompose it, precipitating the lead in the state of muriate or sulphate. According to the analysis of Vauquelin, it is composed of about

34·9	acid
65·1	oxide
100·0 [†]	

16. Molybdate.

Sp. 16. *Molybdate of lead.* The action of molybdic acid on lead has not been tried; but Scheele ascertained, that when dropped into the solution of lead in nitric or muriatic acid, molybdate of lead was immediately precipitated.[‡] The precipitate from nitric acid is redissolved by adding nitric acid.[§]

This salt occurs native in Carinthia. Its composition was first detected by Klaproth. It has a yellow colour, and is completely insoluble in water. Its specific gravity is 5·706.[||] Its crystals are cubic or rhomboidal plates. When heated, it decrepitates and melts into a yellowish mass. It is soluble in fixed alkalies and in nitric acid. Muriatic acid decomposes it by the assistance of heat, and carries off the lead. According to the analysis of Klaproth, it is composed of about

34·7	acid
65·3	oxide
100·0 [**]	

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[*] Berzelius, Nicholson's Journal, xxxv. 45.

[†] Jour. de Min. No. xxxiv. p. 790.

[‡] Scheele, i. 246.

[§] Hatchett, Phil. Trans. 1796.

[||] Hatchett, Phil. Trans. 1796.

[**] Beitrage, ii. 275.

Sp. 17. *Tungstate of lead.* Nitrated tungstate of potash occasions a white precipitate in nitrate of lead.*

18. Acetate.

Sp. 18. *Acetate of lead.* Acetic acid, as Scheele † first, and Vauquelin afterwards, showed, does not attack lead in close vessels; but it occasions its oxidizement when the lead is in contact both with the acid and the air, and the oxide is dissolved as it forms. It dissolves the yellow oxide very readily, and forms with it three salts; the first is the neutral salt, the second contains an excess of base, and the third is a subacetate composed of 4 atoms acid + 5 atoms oxide of lead.

(1.) *Acetate of lead* has been long known. It is mentioned by Isaac Hollandus and Raymond Lully. It received formerly a great variety of names; such as, *sugar of lead*, *sugar of Saturn*, *salt of Saturn*, &c.

This salt is employed in considerable quantities by dyers and calico-printers. They mix it with alum or with sulphate of iron, and by that means compose acetate of alumina or of iron, according to the process; salts which answer much better as mordants for fixing their colours than alum or green vitriol. It is prepared in considerable quantities both in this country and in Holland and France. The manufacturers distil their own acid in England and Holland from sour beer, and in France from sour wine. The different processes followed by manufacturers have been described by Weber ‡ and Demachy, § and more lately by Pontier. ||

Preparation.

These processes may be reduced to two; either lead in the metallic state is exposed to the action of the acetic acid, or the carbonate of lead is dissolved in it. In the first case, thin plates of lead are put into earthen vessels along with acetic acid. The portion of the lead near the surface, as soon as it is covered with a coat of oxide, is removed to the bottom of the vessel, and new plates are brought to the surface. These are incrusted in their turn, and removed to the bottom, where the oxide is dissolved. This change of place is continued daily till the acid has dissolved a sufficient quantity of lead. It is then filtered, and sufficiently concentrated by evaporation. As it cools, the acetate of lead precipitates in small crystals.

Other manufacturers dissolve the carbonate of lead, prepared by exposing the metal to the fumes of vinegar; or they

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* Scheele, ii.

† Crell's Annals, iii. 8. Eng. Trans.

‡ Phys. Chem. Magazin. i. 81.

§ Laborant in grossen, ii. 191.

|| Ann. de Chim. xxxvii. 268.

make use of litharge in its stead, and the solution is evaporated in the usual way till the salt crystallizes. This process is considered as more expensive than the other: but might not native carbonate of lead, which is found abundantly in many places, be employed with advantage instead of these artificial oxides?

Properties.

Acetate of lead is usually in the form of small rhomboidal prisms terminated by an oblique rhomboidal face. They have a glossy appearance like satin. Its taste is sweet and somewhat astringent. Its specific gravity is 2·345.* When water is boiled upon this salt, it dissolves about ·29, and retains in solution when cold about ·27 of its weight of it.† When exposed to the air, it undergoes no change. Its constituents are easily separated. When it is dissolved in water, a small quantity of white powder usually falls. It is carbonate of lead, formed by the carbonic acid, which usually exists in water. When we blow through a solution of acetate of lead, the same white powder precipitates.‡ 200 gr. of alcohol of 0·835 dissolve 15·7 gr. of acetate of lead at 60°.

Products from its distillation.

This salt is decomposed by all those acids and their compounds which form with lead a salt nearly insoluble in water; as the sulphuric, phosphoric, muriatic, fluoric, oxalic, malic, &c. When heated, it is decomposed; and if it be distilled in a retort, very singular products are obtained. These products were first examined by Beccher; afterwards by Baumé, and more particularly by Pluvinet: but it is to Proust that we are indebted for the most precise information on the subject. By distilling 160 parts of sugar of lead, he obtained by a gentle heat 12 parts of water slightly acidulated with vinegar. Then by increasing the fire, there came over 72 parts of a yellow liquid, having the odour of alcohol, strong and agreeable, though mixed with an empyreumatic smell. When lime is added to the liquid, ammonia is disengaged, which existed in the liquid, combined with a slight excess of acetic acid. When the liquid was saturated with potash, and allowed to remain for 24 hours, about one-third of a part of oil separated and floated on its surface. This oil being separated by a syphon, was found to have a strong odour. The liquid was

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Bostock, Nicholson's Jour. xi. 79. Wenzel affirms, that water at the temperature of 100° dissolves its own weight of this salt. Verwandtschaft, p. 308. But this is a mistake.

‡ Proust, Jour. de Phys. lvi. 207.

then distilled by means of a low heat. The first eight parts which came over were of the specific gravity 0·88. This liquid mixed with water exactly like alcohol. Its taste was strong, and its volatility scarcely inferior to that of ether. It burns rapidly, and with a large white flame, when brought near a lighted candle. It contained manifestly a considerable portion of water.* During the distillation abundance of carbonic acid gas is disengaged, but no sensible portion of any other elastic fluid. The constituents of acetate of lead are

	†	‡	§
Acid	26	26·96	26·84
Base	58	58·71	58·95
Water	16	14·32	14·21
	100	100·00	100·00

(2.) *Subtritacetate.* The nature of this salt was first pointed out by Scheele; || but Thenard first investigated its properties with precision.** It may be formed by boiling together in water 100 parts of the sugar of lead, and 150 parts of dry litharge deprived of carbonic acid. Its taste is less sweet; it is less soluble in water; and it crystallizes in plates. It is composed, according to Berzelius, of the following proportions:

Acid	13·23	100
Base	86·77	656
	100·00	

Hence it is a compound of 1 atom acid, and 3 atoms oxide of lead.

Goulard's extract.

The solution of the oxide of lead in acetic acid was strenuously recommended by Goulard, a surgeon in Montpelier, as an excellent application in cases of inflammation. It was prepared by boiling distilled vinegar on litharge till it refused to dissolve any more of the oxide. This preparation was distinguished by the names of *Goulard's extract* and *vinegar of lead.* Scheele first ascertained the nature of this substance, by showing that solution of sugar of lead in water is converted

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* Proust, Jour. de Phys. lvi. 209.

† By my analysis.

‡ Berzelius, Annals of Philosophy, v. 175.

§ Theoretical composition, supposing the salt composed of 1 atom acid, 1 atom oxide, and 3 atoms water.

|| Crell's Annals, iii. 8. Eng. Trans.

** Nicholson's Journal, vi. 223.

into Goulard's extract, by keeping in it a plate of lead for the space of a day; and by proving that the solution oxidized and dissolved a portion of the plate.* But subsequent writers had overlooked the observations of this chemist, till Dr. Bostock examined Goulard's extract, and by comparing it with sugar of lead, showed that it is in reality a solution of *subacetate of lead* in water.† It is precipitated in much greater proportion by carbonic acid than the acetate; and it is a much more delicate test for mucilage or gum, as was known to chemists long before Mr. John Hunter employed it as a reagent.

(3.) *Subacetate.* This salt crystallizes in large flat rhomboidal prisms with angles of 106° and 74°. Each prism is terminated by a dihedral summit, formed by two faces proceeding from the narrow faces of the prism, and meeting at an angle of 130°. These crystals are not altered by exposure to the air. The taste of the salt is sweet and astringent, similar to the taste of common sugar of lead. Its specific gravity is 2·575. At the temperature of 60°, 100 parts of water dissolve 34·8 parts of the salt. It dissolves likewise in alcohol. When heated it melts and boils, giving out first water and then acetic acid. It becomes solid all at once. It is then an orange-coloured powder, consisting entirely of a mixture of two parts protoxide of lead, and one part of lead. The constituents of this salt, according to my analysis, are as follows:

Acetic acid	22
Protoxide of lead	59
Water	19
	100

So that it is composed of 4 atoms acetic acid + 5 atoms protoxide of lead + 19 atoms water.‡

19. Benzoate.

Sp. 19. *Benzoate of lead.* Benzoic acid dissolves lead with difficulty. The solution yields by evaporation crystals of benzoate of lead of a brilliant white colour, soluble in alcohol and water; not altered by exposure to the air, but decomposed by heat, which drives off their acid. The sulphuric and muriatic acids separate the lead.§ This salt is composed as follows:

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* Crell's Annals, iii. 10. Eng. Trans.

† Nicholson's Jour. xi. 75.

‡ Annals of Philosophy, xiv. 382.

§ Trommsdorf, Ann. de Chim. xi. 316.

	*	†
Acid	49·66	49·79
Base	46·49	46·47
Water	3·85	3·74
	100·00	100·00

Berzelius obtained a subbenzoate of lead by digesting the neutral benzoate in caustic ammonia. He found it composed of 1 atom acid + 3 atoms oxide of lead, or by weight of

Benzoic acid	26
Protoxide of lead	74
	100

20. Succinate. Sp. 20. *Succinate of lead.* Succinic acid scarcely attacks lead, but it dissolves its yellow oxide; and the solution, according to Wenzel, yields long slender foliated crystals,‡ scarcely soluble in water, but soluble in nitric acid. Succinic acid does not precipitate lead from nitric or muriatic acid; but it occasions a precipitate in acetate of lead. § The constituents of this salt are as follows:

	‖	**
Acid	30·9	30·86
Base	69·1	69·14
	100·0	100·00

By digesting the neutral succinate in ammonia, Berzelius obtained a subsuccinate composed of 1 atom acid + 3 atoms oxide of lead. Its constituents were

Succinic acid	13·07	100
Oxide of lead	86·93	666
	100·00	

Sp. 21. *Suberate of lead.* Suberic acid precipitates lead from the acetic and nitric acids.††

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* Berzelius, Annals of Philosophy, v. 181.

† Theoretical composition, supposing it composed of 1 atom acid, 1 atom oxide, and 1 atom water.

‡ Wenzel's Verwand. p. 241.

§ Stockar de Neuforn de Succino, § 33, as quoted by Gren, Handbuch, iii. 281.

‖ Berzelius, Annals of Philosophy, v. 100.

** Theoretical composition.

†† Bouillon Lagrange, Ann. de Chim. xxiii. 48.

22. Oxalate.

Sp. 22. *Oxalate of lead.* Oxalic acid blackens lead, but it is scarcely capable of dissolving it; but it dissolves its protoxide, and when nearly saturated deposites small crystalline grains of oxalate of lead. The same crystals are precipitated when oxalic acid is dropped into the nitrate, muriate, or acetate of lead dissolved in water. They are insoluble in alcohol, and scarcely soluble in water, unless they contain an excess of acid. The constituents of this salt are

	*	†
Acid	24·54	24·366
Oxide	75·46	75·634
	100·00	100·000

Sp. 23. *Mellate of lead.* Mellitic acid occasions a white precipitate when dropped into nitrate of lead; but the precipitate is re-dissolved by the addition of nitric acid.[‡]

24. Tartrate.

Sp. 24. *Tartrate of lead.* Tartaric acid has no action on lead; but it combines with its oxide, and precipitates tartrate of lead, in the state of a white powder, from the nitrate, muriate, and acetate of that metal. This salt is completely insoluble in water.[§] Its constituents, according to the respective analyses hitherto made, are as follows:

	‖	**	††	‡‡	§§
Acid	34	37	37·44	37·5	37·43
Yellow oxide	66	63	62·56	62·5	62·57
	100	100	100·00	100·0	100·00

Sp. 25. *Tartrate of potash-and-lead.* This triple salt may be formed by boiling tartar and oxide of lead together in water. Thenard informs us that it is insoluble, and that it is neither decomposed by alkalies nor by sulphates.[‖‖]

Sp. 26. *Citrate of lead.* Citric acid does not attack lead; but when dropped into acetate of lead, a citrate precipitates in

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[*] Berzelius, Annals of Philosophy, v. 97.

[†] Theoretical composition.

[‡] Klaproth's Beitrage, iii. 132.

[§] Bucholz, Gehlen's Jour. v. 269.

[‖] Thenard, Ann. de Chim. xxxviii. 37.

[**] Bucholz, Gehlen's Jour. v. 269.

[††] By my analysis.

[‡‡] Berzelius, Annals of Philosophy, v. 95.

[§§] Theoretical composition.

[‖‖] Thenard, Ann. de Chim. xxxviii. 36.

the state of a difficultly soluble powder.[*] The constituents of this salt are

	[†]	[‡]
Acid	34·18	34·5
Oxide	65·82	65·5
	100·00	100·0

Sp. 27. *Saclactate of lead.* Saclactic acid occasions a white precipitate when dropped into nitrate of lead.[§] It is very easily acted on by heat, the acid becoming brown at a moderate temperature. The constituents of this salt are as follows:

	[‖]	[**]
Acid	48·33	48·28
Base	51·66	51·72
	100·00	100·00

28. Malate. Sp. 28. *Malate of lead.* Malic acid does not attack lead; but when poured into a solution of lead in nitric or acetic acid, malate of lead is immediately precipitated;[††] and likewise, as Vauquelin has observed, when acetate of lead is poured into a solution containing malate of lime. This precipitate is easily distinguished by the form of fine light flakes which it has, and by the facility with which it is dissolved by the acetic and weak nitric acids.[‡‡] We learn from the experiments of Mr. Donovan, that there are three subspecies of this salt.

1. *The neutral malate.* If obtained by precipitation it is a white powder; but if obtained from solution in its own acid it is in beautiful silvery crystals. It is quite insoluble in water.

2. *Submalate.* A white insoluble matter. If in mass, it is dense and hard; if in powder, it is gritty.

3. *Supermalate.* This salt never assumes the solid form. It has a sweet taste.[§§]

29. Lactate. Sp. 29. *Lactate of lead.* Lactic acid unites in three differ-

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[*] Wenzel's Verwandtschaft, p. 184.

[†] Berzelius, Annals of Philosophy, v. 93.

[‡] Theoretical composition.

[§] Scheele, ii. 80.

[‖] Berzelius, Annals of Philosophy, v. 180.

[**] Theoretical composition.

[††] Scheele, Crell's Annals, ii. 7. Eng. Trans.

[‡‡] Ann. de Chim. xxxv. 155.

[§§] Donovan, Phil. Trans. 1815.

ent proportions with oxide of lead, and forms three different saline compounds.

1. *Neutral lactate.* It is obtained by digesting an alcoholic solution of lactic acid on finely powdered litharge, till the liquid acquires a sweet taste. The liquid being then evaporated to the consistence of honey, deposites the lactate in small grains, which may be purified by washing them in alcohol. When dry they are light and silvery. They are not changed in the air. When treated with sulphuretted hydrogen, pure lactic acid may be obtained.

2. *Superlactate.* When lactic acid is digested on carbonate of lead it becomes browner than before; but cannot be fully saturated by the oxide. We obtain an acid salt which does not crystallize, but dries into a syrup like brown mass, with a sweet austere taste.

3. *Sublactate.* If we digest lactic acid on a greater proportion of litharge than is necessary for its saturation, the liquid acquires at first a browner colour; but, as the digestion proceeds, the colour becomes lighter, and the oxide swells into a bulky powder. If the whole be evaporated to dryness, boiled in water, and the liquid filtered while hot, it deposites on cooling a light yellow powder, which is sublactate of lead. When dried it is mealy and soft to the touch. It is decomposed by the weakest acids. When warmed and set on fire at one point it burns like tinder, and leaves the lead in a great measure reduced. According to the experiments of Berzelius, this salt is composed of

Acid	17
Oxide of lead	83
	100

But he considers the proportion of lead thus stated as too high.* Were we to suppose the salt a compound of 1 atom acid + 3 atoms oxide, the weight of an atom of lactic acid deduced from it would be 8·716. We may consider 8·750 as an approximation, which would reduce the proportion of oxide of lead a little.

30. Gallate. Sp. 30. *Gallate of lead.* Berzelius prepared this salt in the following manner. He dissolved gallic acid in a very small quantity of water and added solid carbonate of ammonia.

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* Berzelius, Djurkemien, ii. 439.

When the effervescence was over, he exposed it along with sulphuric acid under the receiver of an air pump exhausted of air. The ammonia first evaporated and then the water. The dry saline mass was dissolved in warm water and mixed with a boiling solution of nitrate of lead, the whole being put into a phial was digested till the gallate assumed the form of grains. These were repeatedly washed with hot water and then dried between folds of blotting paper. Gallate of lead thus prepared is a white crystalline powder with a shade of grey. When exposed to the air it becomes brown. Its constituents are as follows:

	*	†
Acid	36·5	36
Base	63·5	64
	100·0	100

31. Tannate.

Sp. 31. *Tannate of lead.* Berzelius prepared this salt in the following manner. The cold infusion of nutgalls was as nearly as possible neutralized by means of ammonia. It was then mixed with muriate of barytes. A copious precipitate of tannate of barytes fell. This was separated by the filter and washed with care. This tannate being mixed with dilute sulphuric acid, furnished supertannate of barytes soluble in hot water. To the solution he added sulphuric acid till almost the whole barytes was precipitated. The liquid being now filtered had a very astringent taste and reddened litmus paper. Ammonia was added to it till the tannate of barytes began to precipitate. The whole was now mixed with nitrate of lead as long as any precipitate fell. This precipitate being boiled in water as long as any tannin was separated was neutral tannate of lead. It was dried in a vacuum and then subjected to analysis. Its composition is as follows:

	‡	§
Tannin	65·79	65·54
Oxide of lead	34·21	34·46
	100·00	100·00

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* Berzelius, Annals of Philosophy, v. 177.

† Theoretical composition. ‡ Annals of Philosophy, v. 183.

§ Theoretical composition, on the supposition that an atom of tannin weighs 26·625. But if the weight of an atom of tannin is only 8·875, as I conceive, then the tannate in the table will be a compound of 3 atoms tannin and 1 atom oxide of lead, and what Berzelius considers as a subtannate will in reality be the neutral tannate.

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When the tannate of lead is digested in ammonia no change is produced, but if tannate of ammonia be mixed with a boiling solution of subnitrate of lead a subtannate is obtained. It had a white colour, and when dried became greenish, but he did not succeed in making a satisfactory analysis of it.

Such are the properties of the salts of lead as far as they have been examined. As so great a proportion of them is insoluble in water, they answer well for enabling us to determine the equivalent number for the different acids that compose them. Berzelius has taken advantage of this property. It was chiefly by means of them that he was enabled to analyse the different vegetable acids.

The composition of the salts of lead is easily determined by considering them as compounds of 1 atom oxide of lead with 1 atom of each of the acids. The weight of an atom of protoxide of lead is 14, and that of the acids has been given in a preceding chapter of this volume.

Of the salts of lead the acetate and carbonate are the most useful. The acetate is chiefly employed to procure acetate of alumina or acetate of iron by means of double decomposition, in order to be employed as mordants. The carbonate under the name of white lead is very much used as a paint. The chromate of lead forms likewise a very beautiful paint.

SECT. XXVI.

SALTS OF TIN.

Though several of the salts of tin are of great importance in the art of dyeing, and have been known to manufacturers ever since the discovery of the scarlet dye, of which the oxide of tin constitutes a necessary ingredient, it is only of late that the nature and constitution of these salts have been examined with any kind of precision, and that a satisfactory explanation has been given of the curious properties which some of them possess, and the great changes to which they are liable. For the progress which this branch of the science has made, we are chiefly indebted to Adet, Pelletier, and Proust.

Tin, like iron, combines with two doses of oxygen, and forms two distinct oxides, with each of which several of the acids are capable of combining; and those salts which contain the metal oxidized to a minimum are extremely ready to absorb oxygen, and to pass into the state of oxygenized salts. The salts of tin may be distinguished by the following properties:

Characters.

1. Most of them are more or less soluble in water, and the solution has usually a yellowish or brownish tinge, but is sometimes colourless.

2. Ferro-chyazate of potash occasions a white precipitate when dropped into these solutions.

3. Hydrosulphuret of potash occasions a brown-black precipitate in the salts containing the protoxide of tin; a golden yellow precipitate in those that contain the peroxide.

4. Neither gallic acid nor the infusion of nutgalls occasion any precipitate.

5. Corrosive sublimate throws down a black precipitate from the salts of tin containing the protoxide, a white precipitate from those that contain the peroxide.

6. When a plate of lead is put into some solutions of tin, that last metal is separated either in the state of metal, or of white oxide: but this does not happen in every solution of tin.

7. When muriate of gold is poured into solutions containing tin combined with a minimum of oxygen, a purple-coloured precipitate falls.

The salts of tin were formerly distinguished by the epithet *Jovial*, because *Jupiter* was the name by which the alchymists distinguished that metal.

1. Nitrate.

Sp. 1. *Nitrate of tin.* Nitric acid acts with amazing energy upon tin, and converts it into an oxide with the evolution of a great deal of heat; but there seems to be but a very feeble affinity between that acid and the oxides of tin. Hence the union which they form is but of transient duration, the oxides separating when any attempt is made to concentrate the solution. This has been long known to chemists, and has occasioned a variety of attempts to make the solution of tin in nitric acid more permanent: but these attempts, as might have been expected, have not been attended with success.

Action of nitric acid on tin.

When nitric acid of the specific gravity 1·114 is poured upon tin, the metal is dissolved rapidly with effervescence and a great elevation of temperature, which ought to be moderated by plunging the vessel containing the mixture in cold water. In this case the oxygen is chiefly furnished by the water, and the tin is only combined with a minimum of oxygen. The solution, therefore, which is of a yellow colour, is a real *nitrate* of tin. It becomes gradually opaque, and deposits a white powder, which is an oxide of tin with a minimum of oxygen, as Proust has demonstrated. This oxide separates in great abundance if the solution be heated. During the solution of the tin a quantity of ammonia is formed. When potash is dropped into the liquid, this ammonia becomes sensible by its odour. Hence we see that, during the solution, both water and nitric acid have been decomposed; their oxygen combined with the tin, and the hydrogen of the one uniting with the azote of the other, formed ammonia. If a little nitric acid be poured in and heat applied, the tin precipitates in the state of a peroxide.*

No pernitrate.

When nitric acid, of the specific gravity 1·25, is poured upon tin, a very violent action takes place, the metal is oxidized to a maximum, and the whole of it separates from the liquid. Hence we see that there is no *pernitrate* of tin; the peroxide of that metal, not being susceptible of entering into combination with nitric acid. When the liquid is evaporated, nitrate of ammonia is obtained. Morveau found, that 1 part of strong nitric acid and 1½ part of tin, when treated in a retort, gave out no gas, notwithstanding the violence of their action. Upon examining the liquid, he found that the ammonia formed amounted to $\frac{1}{20}$th of the weight of the whole.† Hence we see that during the oxidation, both the acid and the water are decomposed; and that they are decomposed in such proportions, that their hydrogen and azote combine, and form ammonia, while the whole of their oxygen unites with the tin.

2. Carbonate.

Sp. 2. *Carbonate of tin.* As far as is known at present, the oxides of tin do not combine with carbonic acid. Bergman failed in his endeavours to form this combination; and when the oxides of tin are precipitated from their solution in acids by alkaline carbonates, he found that their weight receives scarcely a perceptible increase.‡ Nor have the attempts of Proust to combine these bodies with carbonic acid been attended with more success.§

Sp. 3. *Borate of tin.* Boracic acid does not attack tin; but borax produces a precipitate in the muriate of tin. The white

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* Proust, Jour. de Phys. li. 173.

† Encyc. Method. Chim. i. 632.

‡ Opusc. ii. 329.

§ Jour. de Phys. li. 167.

powder which falls is insoluble in water: in a strong heat it melts into an opaque slag.*

4. Phosphate.

Sp. 4. *Phosphate of tin.* Phosphoric acid has scarcely any action on tin unless when it is exposed dry and mixed with that metal to the action of a strong heat. In that case, part of the acid is decomposed, its phosphorus combines with one portion of the tin and forms a phosphuret, while the oxide of tin unites with the undecomposed acid and forms a phosphate.† This salt precipitates also when the alkaline phosphates are mixed with a solution of muriate of tin; and it may be formed by digesting oxide of tin in phosphoric acid. It is insoluble in water. Tin does not precipitate copper from muriatic acid. Phosphate of tin melts into a glass when heated.‡

5. Sulphate.

Sp. 5. *Sulphate of tin.* When a cylinder of tin is plunged into sulphuric acid, scarcely any action can be perceived for some time; but the metal is gradually converted into white flakes on the surface, which fall to the bottom, and remain in the state of a white powder; at the same time bubbles of sulphurous acid make their escape. The properties of the compounds which this acid forms with tin have not been examined with accuracy. Kunkel, Wallerius, and Monnet, the chemists who have paid the greatest attention to the action of sulphuric acid on tin, attempted the solution by means of heat. In that case the acid is decomposed, sulphurous acid exhaled, and even sulphur developed, if the heat be long enough continued. The metal is oxidized to a maximum, and the *persulphate* obtained is not crystallizable; but when evaporated assumes the form of a jelly; and when water is poured into the solution, the salt precipitates in the state of a white powder.

But if the action of the acid is not assisted by heat, or if tin combined with a minimum of oxygen be dissolved in sulphuric acid in either of these cases a *sulphate* of tin is formed, which yields, when evaporated, crystals in the form of fine needles, as was observed long ago by Monnet. The simplest method of obtaining this salt is that which was pointed out by Berthollet, junior. Pour sulphuric acid into muriate of tin; a white powder falls, which is the sulphate. It dissolves in water, and forms by evaporation small prismatic crystals. Alkalies decompose it imperfectly throwing down a subsulphate of tin.§

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* Wenzel's Verwandtschaft, p. 252.

† Pelletier, Ann. de Chim. xiii. 16.

‡ Wenzel's Verwandtschaft, p. 175

§ Statique Chimique, ii. 464.

6. Sulphite.

Sp. 6. *Sulphite of tin.* The action of sulphurous acid upon tin was examined by Fourcroy and Vauquelin, during their experiments on the combinations which that acid is capable of forming. When a plate of tin is plunged into liquid sulphurous acid, it assumes a yellow colour, and afterwards becomes black. A black powder is precipitated, which is sulphuret of tin. A portion of the acid is decomposed; the tin is partly oxidized, and combined with the remainder of the acid, and partly precipitated in the state of sulphuret combined with the sulphur of the decomposed acid. There remains in solution hyposulphite of tin; for sulphur precipitates when sulphuric acid is added to the solution.*

Sp. 7. *Hyposulphite of tin.* Muriate of tin occasions no precipitate in the solution of an alkaline hyposulphite. Hence the hyposulphite of tin must be a soluble salt.†

Sp. 8. *Seleniate of tin.* The perseleniate of tin is a white powder insoluble in water, but soluble in muriatic acid, from which it is precipitated by water. Heat decomposes it.‡

Sp. 9. *Arseniate of tin.* When tin is treated with arsenic acid in a digesting heat, it is slowly oxidized at the expense of the acid, and the solution at last assumes the form of a gelatinous mass. Arsenic acid precipitates tin from acetic acid, and the alkaline arseniates occasion a precipitate when poured into muriate of tin. The precipitate is arseniate of tin in the form of an insoluble powder, which hitherto has not been examined.§

Action of vinegar on tin vessels.

Sp. 10. *Acetate of tin.* Acetic acid attacks tin very slowly, even when assisted by heat, and oxidizes and dissolves only a small portion of it. The spontaneous action of this acid on tin vessels, when in the state of vinegar, has been lately examined by Vauquelin. The subject was of importance, because vinegar is usually measured out in tin vessels. Now, as these vessels contain always a little lead, and as the salts of lead are all poisonous, it was of consequence to determine whether the vinegar acted on the vessel, and if it did, whether its action was confined to the tin or extended also to the lead; because in this last case the vinegar would be converted into a poison. The result of this investigation was, that a small portion of tin was dissolved; and that when the lead exceeded the sixth part of the tin, a small portion of it was also dissolved at that part

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* Fourcroy, vi. 30.

† Herschell, Edin. Phil. Jour. i. 24.

‡ Berzelius, Ann. de Chim. et de Phys. ix. 341.

§ Scheele, i. 180.

of the vessel only which was in contact both with the vinegar and the air.[*]

When acetic acid is boiled upon tin, the metal is gradually dissolved, combining with oxygen at the expense of the water. The solution has a whitish colour, and yields by evaporation small crystals. This fact, first mentioned by Lemery, had been denied by Monnet, Westendorf, and Wenzel, who could only obtain from it a gummy mass. But Morveau established the truth of Lemery's observation, by crystallizing acetate of tin by spontaneous evaporation.[†] It is easy to account for the different results obtained by these chemists. The crystals were, no doubt, *acetate* of tin, the gummy mass *peracetate* of tin. The simplest method of obtaining the acetate of tin is to mix together the solutions of muriate of tin and acetate of lead.

11. Benzoate.

Sp. 11. *Benzoate of tin.* Neither tin nor its oxide is soluble in benzoic acid; but when benzoate of potash is poured into a solution of tin in nitro-muriatic acid, benzoate of tin precipitates. It is soluble in water by the assistance of heat, but insoluble in alcohol, and decomposed by the action of heat.[‡]

Sp. 12. *Succinate of tin.* Succinic acid dissolves the oxide of tin when assisted by heat. The solution by evaporation yields thin, broad, transparent crystals.[§] Neither lead, iron, nor zinc, occasion any change in the solution of this salt.[||]

13. Oxalate.

Sp. 13. *Oxalate of tin.* Oxalic acid attacks tin when assisted by heat. The metal is first blackened, and is then covered with a white crust of oxide. The solution, which has an austere taste, by slow evaporation yields prismatic crystals; but when evaporated rapidly by means of a strong heat, it leaves a mass resembling horn.[**]

Sp. 14. *Tartrate of tin.* The tartrate of tin has never been examined by chemists. The acid does not attack the metal, but it dissolves the oxide of tin.

Sp. 15. *Tartrate of potash-and-tin.* This triple salt may be formed by boiling together tartar and the oxide of tin in water. It is very soluble, and therefore its solution crystallizes with difficulty. No precipitate is produced in it by the alkalies or their carbonates.[††]

Sp. 16. *Nitrate of ammonia-and-tin.* The peroxide of tin

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[*] Ann. de Chim. xxxii. 243.

[†] Encycl. Method. Chim. i. 23.

[‡] Trommsdorf, Ann. de Chim. xi. 315.

[§] Wenzel's Verwandtschaft, p. 241.

[||] Ibid. p. 252.

[**] Bergman, i. 269.

[††] Thenard, Ann. de Chim. xxxviii. 35.

is insoluble in nitric acid, but it dissolves when treated with nitric acid and ammonia. Hence the reason why a salt containing tin is often procured by the action of nitric acid on tin. Nitrate of ammonia is formed during the process.*

SECT. XXVII.

SALTS OF COPPER.

These salts, in consequence of the facility with which copper absorbs oxygen, are in general more easily formed, and of course may be more readily examined than several of the other genera. Hence no doubt the reason that some of them have been so long and so generally employed. The alchymists and the earlier chemists distinguished them by the names of *salts of Venus,* because Venus was the term which they gave to copper.

The cupreous salts may be distinguished by the following properties:

Characters. 1. They are almost all soluble in water, or at least become so by the addition of an acid. This solution has either a blue or a green colour, or it acquires that colour after being for some time exposed to the air.

2. When ammonia is poured into this solution, it assumes a deep-blue colour.

3. Ferrochyazate of potash occasions a red coloured precipitate when poured into a cupreous solution.

4. Hydrosulphuret of potash occasions a black precipitate.

5. Gallic acid occasions a brown precipitate.

6. A plate of iron, when plunged into a liquid salt of copper, precipitates the copper in a metallic state.

Almost all the acids, as far as is known, combine only with copper oxidized to a maximum; so that, strictly speaking, all the salts of copper are persalts.

1. Nitrate. Sp. 1. *Nitrate of copper.* Nitric acid attacks copper with considerable violence; nitrous gas is emitted in great purity, while the metal is oxidized and dissolved. The solution is of a fine blue colour; and when slowly evaporated yields regular crystals of nitrate of copper.

Properties. These crystals are long parallelopipeds. Their specific gravity is 2·174.† They have a fine blue colour; their taste is

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* Thenard, Ann. de Chim. xlii. 218.

† Hassenfratz, Ann. de Chim. xxviii. 12.

acrid and metallic; and they are exceedingly caustic, corroding the skin with great energy. They are very soluble in water; and when exposed to the air, gradually attract moisture, and deliquesce. At a heat not exceeding 100° they undergo the watery fusion; and if the heat be increased, they lose their water and part of their acid. On burning coals they detonate feebly. These crystals detonate also when mixed with phosphorus and struck with a hammer, as Brugnatelli first observed. When a quantity of them, moistened with water, is wrapt up in a sheet of tinfoil, they act with amazing energy upon that metal, nitrous gas is emitted, a strong heat is produced, the tinfoil is burst open in every direction, and very often it takes fire. This curious experiment was first made by Dr. Higgins.*

The constituents of this salt, according to my analysis, are

Nitric acid	37·05
Peroxide of copper	30·95
Water	32·00
	100·00

Subnitrate. When potash is poured into a solution of nitrate of copper, a blue precipitate appears, which soon becomes green by agitation, provided the quantity of potash be insufficient to decompose the whole of the nitrate. Mr. Proust has proved, that this green precipitate is a subnitrate of copper. It may be obtained also by distilling nitrate of copper in a retort. At a particular period of this process the salt becomes thick, and encrusts the retort in the state of a green lamellar concretion. It is then converted into subnitrate. This salt is completely insoluble in water. Sulphuric acid separates its acid; and the same separation may be effected also by distillation. Berzelius likewise examined this subnitrate which he obtained by various processes, but found it always the same. Its constituents are as follows:

	†	‡	§
Acid	16	18·9	21·6
Oxide	67	66·0	64·0
Water	17	15·1	14·4
	100	100·0	100·0

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* Phil. Trans. lxiii. 137.

† Proust, Ann. de Chim. xxxii. 26.

‡ Berzelius, Ann. de Chim. lxxxii. 250.

§ Theoretical composition, on the supposition that the salt is composed of 1 atom acid, 2 atoms peroxide, and 4 atoms water.

Nitric acid does not seem to combine with protoxide of copper. When concentrated, it oxidizes the metal to a maximum, and then dissolves it: when diluted, one part of the metal attracts oxygen from the other: blue nitrate is formed, and a red powder precipitates, which is copper reduced.*

2. Nitrite. Sp. 2. *Nitrite of copper.* This salt may be obtained by mixing the requisite quantity of nitrite of lead with sulphate of copper. Sulphate of lead precipitates and the liquid contains in solution nitrite of copper which gives it a green colour. It is gradually decomposed when left exposed to the air, and the decomposition is very speedy when the liquid is digested in an open vessel. When nitrate of copper is digested over metallic copper, no nitrite of copper is formed.†

3. Carbonate. Sp. 3. *Carbonate of copper.* Carbonic acid does not attack copper; but it combines readily with its oxide, or with the hydrate of copper, when that compound is mixed with water, and a current of carbonic acid gas made to pass through it. Or the carbonate may be formed by precipitating a solution of nitrate of copper with a fixed alkaline carbonate.‡ To give the carbonate all its lustre, the solution should be mixed with boiling water, and the precipitate should be washed with great care, and exposed to the light of the sun. It has then a fine apple-green colour, and it is found often native in its greatest beauty. The native carbonate is known among mineralogists by the name of *malachite, blue copper ore,* and *anhydrous carbonate,* according as it is combined with 1 or 2 atoms of water, or destitute of water. It is insoluble in water, and is converted to black oxide of copper by the action of heat. The anhydrous carbonate, by my analysis, is a compound of

Carbonic acid	2·75	100	21·58
Peroxide of copper	10·00	363·6	78·42
			100·00

4. Borate. Sp. 4. *Borate of copper.* When borax is poured into a solution of sulphate of copper, borate of copper is precipitated in the form of a pale light-green jelly, which when dried is with great difficulty soluble in water. It easily melts into a dark-red vitreous substance.§ According to Palm, by long

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* Jour. de Phys. li. 182.

† Berzelius, Ann. de Chim. lxxxiii. 31.

‡ Mr. Chenevix has shown that the alkaline carbonates have the property of dissolving a portion of the oxide of copper, and of forming with it a triple salt.

§ Bergman.

trituration of filings of copper and boracic acid in water, and then digesting the mixture, it dissolves, and crystals may be obtained from it.

5. Silicate.

Sp. 5. *Silicate of copper.* The mineral called by the Germans *emerald copper ore*, and by the French *dioptase*, is a hydrous trisilicate of copper, if we consider the analysis of it by Lowitz as correct. He found its constituents

Silica	33
Peroxide of copper	55
Water	12
	100

If we suppose it a compound of 3 atoms of silica, 1 atom of peroxide, and 2 atoms of water, its constituents will be

Silica	32·88
Peroxide	54·79
Water	12·33
	100·00

Now these numbers almost coincide with the analysis of Lowitz, and fully confirm it.

6. Phosphate.

Sp. 6. *Phosphate of copper.* Phosphoric acid does not attack copper immediately; but when allowed to remain long upon that metal oxidation at length takes place, and the phosphate of copper is formed. This salt may be obtained with great facility by pouring phosphate of soda into a solution of nitrate of copper. A bluish-green powder immediately precipitates, which is phosphate of copper. This salt is insoluble in water. Its specific gravity, according to Hassenfratz, is 1·4158.[*] When exposed to a red heat, it loses its water, and acquires a brown colour. When violently heated, phosphuretted copper comes over. According to the analysis of Mr. Chenevix, it is composed of

Brown oxide	49·5	hydrate of copper	61·5
Water	12		
Acid			35·0
Water			3·5
			100·0[†]

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[*] Ann. de Chim. xxviii. 12.

[†] Phil. Trans. 1801, p. 206.

I have obtained a biphosphate of copper by the process above described. When nitrate of copper was mixed with phosphate of ammonia the precipitate obtained was a sub-phosphate of copper, composed of 1 atom acid and 2 atoms oxide. I have not yet succeeded in obtaining a neutral phosphate of copper, though I am persuaded that such a salt may be formed.

7. Sulphate.

Sp. 7. *Sulphate of copper.* Sulphuric acid does not attack copper while cold; but at a boiling heat part of the acid is decomposed, the copper is oxidized, and combines with the remainder of the acid. But recourse is seldom had to this process, as the sulphate of copper is found native abundantly, dissolved in mineral waters connected with copper mines. From these waters it is often obtained by evaporation: or it is formed by burning native sulphuret of copper, or by moistening that substance and exposing it to the air. By either of these methods the sulphur is acidified, and the sulphate of copper formed. This salt appears to have been known to the ancients. In commerce it is distinguished by the name of *blue vitriol*, and sometimes by that of *blue copperas*. It is in fact a persulphate. There are three subspecies of this salt known, namely, *bisulphate*, *sulphate*, and *subsulphate*.

Properties.

1. *Bisulphate.* This is the subspecies which occurs in commerce, and which is formed by the usual processes. It renders vegetable blues red, and therefore contains an excess of acid. It has a deep blue colour. The primitive form of its crystals, according to Haüy, is an oblique parallelopiped, whose sides are inclined to each other at angles of 124° 1′ and 55° 59′; and whose base makes, with one of the sides, an angle of 109° 21′, and with the opposite side an angle of 70° 39′. It sometimes passes into the octahedron and decahedron, and the edges at the bases are often truncated. It refracts doubly.*

It has a strong styptic metallic state, and indeed is employed as a caustic. Its specific gravity is 2·1943.† It is soluble in about four parts of water at the temperature of 60°, and in 1·6 parts of water at the temperature of 144°.‡ When exposed to the air, it undergoes a very slight efflorescence, and its surface is covered with a greenish white powder. When heated,

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* Prieur, Ann. de Chim. lxvi. 188.

† Hassenfraz, Ann. de Chim. xxviii. 12. According to Dr. Watson, 2·230 (Chemical Essays, v. 69.)

‡ Wenzel's Verwandtschaft, p. 309.

it loses its water, and is converted into a bluish white powder: if the heat be increased, the acid is driven off, and the black oxide of copper remains behind. The constituents of this salt are as follows:

	*	†	‡
Acid	33	31·38	32
Oxide	32	32·32	32
Water	35	36·30	36
	100	100·00	100

This salt is decomposed by the alkalies and earths, the alkaline carbonates, borates, and phosphates, and by those metallic salts whose base forms with sulphuric acid a salt nearly insoluble, as the salts of lead.

It seems to have the property of forming a quadruple salt with muriate of ammonia. When equal parts of the two salts dissolved in water are mixed together, the solution has a yellow colour while warm, but becomes green on cooling. This solution forms a sympathetic ink. Lines drawn with it on paper are invisible while cold; but when the paper is heated they assume a yellow colour, which disappears again when the paper cools.§

2. *Sulphate.* This salt possesses nearly the properties of the first variety, but it crystallizes in four-sided pyramids separated by quadrangular prisms.|| It may be obtained by saturating the excess of acid in the supersulphate with the oxide of copper.

3. *Subsulphate.* When a small quantity of pure potash is poured into a solution of sulphate of copper, a green-coloured powder appears, which swims in the solution. It may be separated by filtration; and when sufficiently edulcorated is insoluble in water. This powder was first examined by Mr. Proust. He has ascertained it to be a subsulphate of copper. Its constituents are

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* Proust, Ann. de Chim. xxxii. 33.

† Berzelius, Ann. de Chim. lxxxii. 121.

‡ Theoretical composition, on the supposition that it is composed of 2 atoms acid, 1 atom oxide, and 10 atoms water.

§ Gillet Laumont, Phil. Mag. xiv. 76.

|| Leblanc, Jour. de Phys. lv. 301.

Composition.

	*	†	‡
Acid	18	21·28	21·39
Oxide	68	64·22	64·17
Water	14	14·50	14·44
	100	100·00	100·00

The experiments of Proust render it probable that sulphuric acid does not combine with the protoxide of copper; for when that acid is poured upon this oxide, one part of the metal attracts oxygen from the other. The consequence is, the formation of blue sulphate of copper, and the precipitation of a red powder, which is copper reduced.

8. Sulphite.

Sp. 8. *Sulphite of copper.* Sulphurous acid combines only with the protoxide of copper, the peroxide having the property of converting it into sulphuric acid. Sulphite of copper may be formed by passing a current of sulphurous acid gas through water containing peroxide of copper mixed with it. The peroxide is gradually converted into protoxide, by giving out one half of its oxygen to a portion of the sulphurous acid, which it converts into sulphuric. The sulphite of copper remains in the state of small red crystals while the sulphate dissolves in the water. This salt may be obtained also by mixing a solution of sulphate of potash with a solution of nitrate of copper, and washing the yellow precipitate that falls till it becomes red. Sulphite of copper is in the state of small red crystals. It is insoluble in cold water; but when long boiled in water, the whole of its acid is separated and nothing remains but protoxide of copper. When heated it gives out water, sulphurous acid, a little sulphur, and some sulphate of copper is formed. Potash and soda readily deprive it of its acid. Chlorine and nitric acid convert it into sulphate of copper. According to Chevreul, to whom we are indebted for the whole of the preceding facts, this salt is composed of

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* Proust, Ann. de Chim. xxxii. 34.

† Berzelius, Ann. de Chim. lxxxii. 240.

‡ Theoretical composition, on the supposition that the salt is composed of 1 atom acid, and 1½ atom oxide, and 3 atoms water; or of 2 atoms acid, 3 atoms oxide, and 6 atoms water.

§ Jour. de Phys. li. 182.

Sulphurous acid	32·18	36·16
Protoxide of copper	56·82	63·84
Water	11·00	
	100·00*	100·00

If we suppose this salt a compound of 1 atom acid + 1 atom protoxide, its composition would be

Acid	30·76
Oxide	69·24
	100·00

Numbers which do not correspond well with those of Chevreul, and therefore render the accuracy of his analysis suspicious.

Sp. 9. *Sulphite of copper-and-potash.* When sulphite of potash is poured into nitrate of copper, a yellow flocky precipitate falls, which gradually diminishes in bulk and assumes the form of small crystals. These crystals are partly red and partly lemon yellow. The red crystals are sulphite of copper; the yellow are a triple salt, composed of sulphite of copper and sulphite of potash united together. According to Chevreul,† they are composed of

Sulphite of copper	73·25
Sulphite of potash	12·68

Sp. 10. *Ammonio-sulphate of copper.* From the experiments of Berzelius, it appears, that this triple salt is a compound of 1 atom sulphate of ammonia and 1 atom of sulphate of copper, each retaining its water of crystallization.‡ Hence the constituents are,

Sulphate of ammonia	7·125
Bisulphate of copper	20·000
Water	14·625
	41·750

So that the weight of an integrant particle of this salt is no less than 41·75.

Sp. 11. *Subsulphate of ammonia-and-copper.* This is the substance known by the name of *cuprum ammoniacum.* Berzelius prepared it by pouring ammonia into a concentrated solution of bisulphate of copper, and then precipitating the blue

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* Ann. de Chim. lxxxiii. 181. † Ibid. 200. ‡ Ibid. lxxxii. 257.

liquor by means of alcohol. The precipitate was washed with alcohol and then dried. Berzelius found its constituents as follows:

Sulphuric acid	32·25
Peroxide of copper	34·00
Ammonia	26·40
Water	7·35
	100·00*

Now if we consider it as a compound of 2 atoms acid, 1 atom peroxide, 4 atoms ammonia, and 2 atoms water, its composition will be

Sulphuric acid	32·52
Peroxide	32·52
Ammonia	27·64
Water	7·32
	100·00

It must be acknowledged that this is a very singular compound. A great part of the ammonia which it contains must be very loosely combined.

Sp. 12. *Sulphate of potash-and-copper.* When bisulphate of potash is digested upon carbonate or peroxide of copper, a green coloured solution is obtained, which yields when sufficiently concentrated by evaporation crystals of a triple salt composed of sulphate of potash united to sulphate of copper. These crystals have a greenish blue colour. They are oblique parallelopipedons, pretty flat, their bases being rhombs and much larger than their sides. Some of the angles and edges are frequently truncated. When held between the eye and the light, two diagonals may be observed crossing the crystal, and of rather a lighter colour than the rest of the crystal. This salt is soluble in water and may be obtained again in crystals unaltered. It suffers no change by exposure to the air. According to the analysis of Vogel of Bayreuth, to whom we are indebted for our knowledge of this salt, its constituents are

Sulphuric acid	36·075
Potash	21·425
Peroxide of copper	18·000
Water	24·500
	100·000†

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* Ann. de Chim. lxxxii. 263.

† Schweigger's Journal, vii. 40.

Now, if we suppose it a compound of 4 atoms acid, 2 atoms potash, 1 atom peroxide of copper, and 12 atoms water, its constituents will be

Sulphuric acid	36·036
Potash	21·621
Peroxide of copper	18·018
Water	24·325
	100·000

Now these numbers almost coincide with the analysis of Vogel. There can be no doubt therefore, that this triple salt is a compound of 2 atoms of sulphate of potash, 1 atom of bisulphate of copper, and 12 atoms water.

Sp. 13. *Hyposulphite of copper.* This salt may be formed by digesting hyposulphite of lime on carbonate of copper, or by mixing sulphate of copper with hyposulphite of lime, potash, &c. It is colourless, of an intensely sweet taste, followed by a mawkish sweetness like liquorice root, but with no metallic flavour. It is not decomposed, nor turned blue by ammonia. It is a protohyposulphite of copper.*

Sp. 14. *Seleniate of copper.* Of this salt there are three subspecies known.

(1.) *Protoseleniate.* It is a white insoluble powder obtained by digesting protoxide of copper in selenic acid.

(2.) *Perseleniate.* When a hot solution of sulphate of copper is mixed with biseleniate of ammonia, a yellow precipitate falls in very bulky flocks. This precipitate rapidly diminishes in volume, and is converted into very brilliant small silky crystals of a greenish-blue colour. These crystals consist of neutral perseleniate. This salt is neither soluble in water, nor in selenic acid. When heated the water of crystallization escapes and the salt becomes liver-brown. At a higher temperature it melts and becomes black. It then begins to boil, gradually allows its acid to escape, and at last nothing remains but peroxide of copper.

(3.) *Subperseleniate.* It is obtained by precipitating sulphate of copper by subseleniate of ammonia. It is an insoluble pistachio-green powder, but soluble in ammonia. When heated it becomes black and allows its water to escape. Then it swells up and its acid is disengaged.†

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* Herschell, Edin. Phil. Jour. i. 24.

† Berzelius, Ann. de Chim. et de Phys. ix. p. 340.

15. Arseniate.

Sp. 15. *Arseniate of copper.* When arsenic acid is digested on copper, the metal is oxidized and dissolved, and a bluish-white powder is formed, which consists of the arseniate of copper. This salt may be formed also by pouring arsenic acid into acetate of copper, or by precipitating nitrate of copper by means of an alkaline arseniate.*

Arseniate of copper has been found native in considerable quantities in the mine of Huel Garland, in the parish of Gwennap in Cornwall; and a very interesting description and analysis of it have been published by the Count de Bournon and Mr. Chenevix in the Philosophical Transactions for 1801.

Varieties.

From the experiments and observations of these celebrated philosophers, it appears that there are no less than five varieties of arseniated copper, differing from each other in the proportion of oxide, acid, and water, which they contain. In general they are insoluble in water, if we except one variety, which seems to be a superarseniate, and which hitherto has not been found native. Their colour varies from a deep-blue to green, and even to brown, yellow, and black. This variation seems to depend upon the proportion of water which they contain, the blue and the green containing most, and the brown least water.

Variety 1. *Obtuse octahedral arseniate.* This variety is crystallized in obtuse octahedrons, composed of two four-sided pyramids applied base to base, the faces of which are isosceles triangles; and two of them which are opposite are more inclined than the others. These meet at the apex at an angle of 130°, and at the base at an angle of 50°. The pyramids often terminate in ridges. These crystals are commonly a deep sky-blue, and sometimes a fine grass-green. Their specific gravity is 2·881.† They are composed, according to the analysis of Chenevix, of

14·3	acid
50·0	brown oxide
35·7	water
100·0	

Variety 2. *Hexahedral arseniate.* This variety is commonly found in very fine six-sided laminæ, and is divisible into thin scales like mica. It is of a deep emerald-green colour; and its specific gravity is 2·548.‡ It is composed of

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* Scheele, i. 175.

† Bournon.

‡ Ibid.

43 acid
39 oxide
18 water

100[*]

This variety precipitates in the form of very small blue crystals when arseniate of ammonia is poured into nitrate of copper.[†]

Variety 3. *Acute octahedral arseniate.* This variety is composed of two four-sided pyramids applied base to base; two of the faces, which are more inclined, meet at the apex at an angle of 84°, and at the base at one of 96°. The other two form at the apex and base angles of 68° and 112°. The apex of the pyramids is often a ridge. Very frequently it assumes the form of a rhomboidal prism, terminated by dihedral summits, and in many cases the angles of 96° are truncated. Its usual colour is brown or dark bottle-green. Its specific gravity is 4·280.[‡] It is composed of

29 acid
50 oxide
21 water

100

But sometimes it is destitute of water altogether.[§]

Variety 4. *Trihedral arseniate.* The primitive form of this variety is a trihedral prism, whose bases are equilateral triangles; but it occurs crystallized in a great variety of figures, which have been described with great accuracy by the Count de Bournon. They are usually of a fine bluish-green colour, and of the same specific gravity as the last species. When opaque they are sometimes nearly black. They are composed, according to the analysis of Chenevix, of

30 acid
54 oxide
16 water

100

Variety 5. *Superarseniate.* This salt has not been found native; but it has been formed by Mr. Chenevix by the following process: Arseniate of ammonia was poured into the

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[*] Vauquelin, Jour. de Men. x. 562.

[†] Chenevix.

[‡] Bournon.

[§] Chenevix.

nitrate of copper, and occasioned a precipitate, which was the second variety described above. The solution, which retained its blue colour, was partially evaporated, and then alcohol was poured into it. Another precipitation took place, and increased considerably on allowing the solution to stand. This precipitate consisted of rhomboidal crystals of a blue colour.* They were composed of

40·1 acid
35·5 oxide
24·4 water

100·0

Perhaps a more precise idea may be formed of the composition of these varieties from the following table, which exhibits the proportion of oxide and water combined in each with 1·00 of acid, according to the analysis of Chenevix:

Composition.

	Acid.	Oxide.	Water.
Variety 1st,	1·00	3·70	2·50
2d,	1·00	2·76	1·00
3d,	1·00	1·72	0·70
4th,	1·00	1·80	0·53
5th,	1·00	0·88	0·60 †

I think it probable that these 5 varieties may be reduced under 4 subspecies, as follows:

Variety 3d and 4th, consist of subarseniate of copper composed of 1 atom acid + 2½ atoms peroxide.

Variety 5, is an arseniate composed of 1 atom acid + 1 atom peroxide + 8 atoms water.

Variety 2d, is a subarseniate composed of 1 atom acid + 1⅓ atoms peroxide + 6 atoms water.

Variety 1st, is a subarseniate composed of 1 atom acid + 5 atoms peroxide.

16. Arsenite.

Sp. 16. *Arsenite of copper.* Arsenious acid forms with peroxide of copper an arsenite, usually distinguished by the name of *Scheele's green,* because Mr. Scheele first examined it, and proposed it as a paint. It may be formed by dissolving two parts of sulphate of copper in 44 parts of water, and likewise two parts of potash of commerce and nearly one part of the white oxide of arsenic pulverised in 44 parts of water

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* Phil. Trans. 1801, p. 207.

† See Haüy's remark on this analysis, Jour. de Min. xiii. 425.

by the assistance of heat. The solution of copper is gradually added while hot to the arsenite of potash, and the whole is often stirred during the mixture. The mixture, on standing, gradually deposites the arsenite of copper in the form of a fine green powder. It is to be washed well with water and then dried.*

17. Antimoniate.

Sp. 17. *Antimoniate of copper.* Antimoniate of potash when dropped into sulphate of copper occasions a precipitate of antimoniate of copper. It is a bulky green precipitate quite insoluble in water. When heated it loses 19 per cent. of water. Before the blow-pipe on charcoal it is reduced with a lively deflagration, leaving a metallic button composed of copper alloyed with antimony.†

Sp. 18. *Antimonite of copper.* This salt may be prepared in the same way as the preceding species, which it resembles in its colour and insolubility in water. A subantimonite of potash precipitates a subantimonite of copper, which resembles arsenite of copper in its appearance.‡

19. Chromate.

Sp. 19. *Chromate of copper.* This salt may be formed by mixing together solutions of chromate of potash, and sulphate of copper. A precipitate falls, at first yellowish-brown, but bistre brown when dried.§

Sp. 20. *Molybdate of copper.* Molybdic acid throws down a green precipitate from nitrate of copper.‖

Sp. 21. *Tungstate of copper.* Tungstic acid and its compounds occasion a white precipitate when poured into the salts of copper.**

22. Acetate.

Sp. 22. *Acetate of copper.* Acetic acid attacks copper very slowly in open vessels, converts it into an oxide, and dissolves it: but in close vessels no action takes place. This acid readily combines with the oxide of copper, and forms with it an acetate. This salt was known to the ancients, and various ways of preparing it are described by Pliny.†† It is usually obtained by exposing plates of copper to the action of vinegar till they are converted to a bluish-green powder called *verdigris*, and then dissolving this powder in acetic acid, and crystallizing it.

Properties.

Acetate of copper crystallizes in four-sided truncated pyra-

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* Scheele, i. 261.

† Berzelius, Nicholson's Jour. xxxv. 43.

‡ Ibid. p. 45.

§ Vauquelin, Ann. de Chim. lxx. 70.

‖ Hatchett.

** Scheele.

†† Lib. xxxiv. c. 11.

mids. It has a beautiful bluish-green colour. Its specific gravity is 1·779.* Its taste is disagreeably metallic, and, like all the compounds into which copper enters, it is poisonous. It is sparingly soluble in cold water. When that liquid is boiled upon the salt, it takes up, according to Wenzel, $\frac{1}{5}$th of its weight of it.† Alcohol likewise dissolves it. When exposed to the air, it effloresces. By distillation it gives out acetic acid. Proust first remarked that acetous acid and acetic acid form the same salt with copper; and hence concluded that there is no difference between the two acids.‡ When sulphuretted hydrogen gas is made to pass through a solution of this salt in water, the copper is deoxidized, and precipitates in the state of a black sulphuret, and there remains behind an acid which possesses the properties of the acetic.§

According to Proust, the acetate of copper is composed of

61	acid and water
39	oxide
100	

If we suppose it a compound of 1 atom acid, 1 atom oxide, and 8 atoms water, its constituents will be

Acetic acid	25·12
Peroxide of copper	39·41
Water	35·47
	100·00

I consider these to be its true constituents.

When verdigris of commerce is put into water, 0·56 parts of it are dissolved, and there remains 0·44 parts in the state of a fine green powder, which continues long suspended in the solution. Mr. Proust has ascertained that this powder is a *subacetate* of copper. It is decomposed by sulphuric acid, by potash, and by distillation. According to the analysis of Proust, it is composed of

37	acid and water
63	oxide
100	

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Verwandtschaft, p. 310.

‡ Jour. de Phys. lvi. 211.

§ Ann. de Chim. xxxii. 36.

Thus it appears, from the experiments of this philosopher, that the verdigris of commerce is composed of two different acetates of copper; the one soluble in water, the other insoluble.[*] It is much used as a paint; and crystallized acetate of copper is a frequent ingredient in dyeing compounds. Verdigris is formed in great quantities at Montpelier. A particular account of the processes followed in that place has been published by Mr. Chaptal.[†]

Sp. 23. *Benzoate of copper.* Benzoic acid does not act upon copper, but it combines readily with the oxide of that metal. The salt formed is in small crystals of a deep-green colour, sparingly soluble in water, and insoluble in alcohol. When heated the acid evaporates and leaves the oxide. The alkalies and the carbonates of lime and barytes decompose it.[‡]

24. Succinate.

Sp. 24. *Succinate of copper.* Succinic acid dissolves copper with difficulty, and only when assisted by a long digestion. The solution is green, and yielded Wenzel small green crystals, the properties of which have not been examined. From the experiments of the same chemist we learn, that there are two varieties of this salt, a *supersuccinate* and a *subsuccinate*. He digested 10 grains of carbonate of copper in succinic acid: an effervescence took place; one portion was dissolved, but another remained at the bottom of the vessel. This portion weighed 17 grains. It had lost its carbonic acid, and evidently contained succinic acid. The solutions contained a portion of copper, which was not separated by an alkali, but by a hydrosulphuret, and zinc threw it down.[§]

Sp. 25. *Suberate of copper.* Suberic acid gives a green colour to nitrate of copper, but occasions no precipitate.[||]

26. Oxalate.

Sp. 26. *Oxalate of copper.* Oxalic acid is capable of attacking copper, and forming with it needle-shaped crystals of a green colour, not altered by exposure to the air.[**] It combines with great facility with its oxide. The oxalate formed is in the state of a bluish-green powder, scarcely soluble in

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[*] In some experiments which I made on verdigris, I obtained 54·3 of insoluble matter, which was a compound of 2 parts carbonate of copper, and 1 part subacetate. No doubt the insoluble portion of verdigris will vary much, both in quantity and composition, according to circumstances.

[†] Ann. de Chim. xxv. 305.

[‡] Trommsdorf, Ann. de Chim. xi. 315.

[§] Wenzel's Lehre von der Verwandtschaft der Korper. Grindel's edit. p. 242.

[||] Bouillon Lagrange, Ann. de Chim. xxiii. 48.

[**] Wenzel, Ann. de Chim. xi. p. 229.

water unless with excess of acid. According to Bergman, to whom we are indebted for all that is yet known of this salt, 21 parts of copper require 29 parts of acid to dissolve them. Oxalic acid precipitates this salt from liquid sulphate, nitrate, muriate, and acetate of copper.*

The constituents of this salt, supposing it composed of 1 atom acid + 1 atom peroxide, are as follows:

Oxalic acid	31·08
Peroxide of copper	68·92
	100·00

Bergman's acid contained nearly half its weight of water.

27. Potash oxalate.

Sp. 27. *Oxalate of potash-and-copper.* When binoxalate of potash is digested on carbonate of copper, a dark sky-blue solution is obtained, which when evaporated deposits crystals distinguished by two different forms. Some of them were needle-form crystals, which speedily effloresced in the air. They consisted chiefly of long slender six-sided prisms. The remaining crystals are oblique parallelopipedons with rhomboidal ends much larger than the lateral faces. These crystals have a greener colour than the first kind, and are not altered by exposure to the atmosphere. From the analysis of Vogel, of Bayreuth, it appears that these two species of salt differ from each other solely in the proportion of their water of crystallization; the first kind containing 8 atoms of water, while the second kind contains only 4 atoms. Both contain 4 atoms of acid, 2 atoms of potash, and 1 atom of peroxide of copper. Hence we must consider each as composed of 2 atoms of oxalate of potash, united to 1 atom of binoxalate of copper, and the first as containing 8 atoms, and the second 4 atoms of water. The following is the result of Vogel's analysis.†

	1st subspecies.	2d subspecies.
Oxalic acid	36·46	40·5
Potash	25·04	27·0
Peroxide of copper	20·50	22·5
Water	18·00	10·0
	100·00	100·0

If we suppose their constituents as above stated, they will be composed as follows:

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* Bergman, i. 267.

† Schweigger's Jour. ii. 435.

	1st subspecies.	2d subspecies.
Oxalic acid	35·47	39·14
Potash	24·98	27·56
Peroxide	20·82	22·97
Water	18·73	10·33
	100·00	100·00

Numbers which almost coincide with the results obtained by Vogel.

28. Soda oxalate.

Sp. 28. *Soda-oxalate of copper.* Vogel of Bayreuth prepared this salt by saturating binoxalate of potash with soda, and pouring a saturated solution of sulphate of copper into the liquid. A pulverulent precipitate fell, which was redissolved by agitation. On evaporating the liquid, the triple oxalate of potash and copper first crystallized. Afterwards crystals of soda-oxalate of copper were deposited. These crystals have a dark sky-blue colour. They are needle-form or feather-shaped, and consist of four-sided prisms, sometimes with all the sides equal, sometimes with two broad and two narrow sides. They are not altered by exposure to the air, at least they neither effloresce nor deliquesce; but they gradually become green, and then dark-brown, without any other apparent alteration; and this change takes place very speedily in the sun's rays. It is insoluble in water without decomposition. According to the analysis of Vogel, the constituents of this salt are as follows:*

Oxalic acid	46·48
Soda	19·02
Peroxide of copper	23·50
Water	11·00
	100·00

If we consider this salt as a compound of 4 atoms acid, 2 atoms soda, 1 atom peroxide of copper, and 4 atoms water, its constituents will be

Oxalic acid	43·10
Soda	20·23
Peroxide of copper	25·29
Water	11·38
	100·00

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* Schweigger's Journal, vii. 21.

Numbers which come sufficiently near the results of Vogel's analysis to show that the salt is composed as has been stated. This triple salt then may be considered as a compound of 2 atoms of oxalate of soda, 1 atom of binoxalate of copper, and 4 atoms of water. It, therefore, agrees with the second subspecies of the preceding salt in its composition.

29. Ammonio-oxalate.

Sp. 29. *Ammonio-oxalate of copper.* Of this salt Vogel of Bayreuth has described three subspecies, which it will be requisite to give an account of separately.

(1.) *Foliated ammonio-oxalate.* This salt was obtained by mixing together a solution of oxalate of ammonia and oxalate of copper, and digesting the mixture. The oxalate of copper soon dissolved, and, by evaporation, small crystals were deposited in the form of rhomboidal plates. These crystals constitute the salt in question. They are not altered by exposure to the atmosphere. They are insoluble in water, but are gradually decomposed by that liquid. When heated, they give out water, and afterwards ammonia. When suddenly heated, they detonate loudly, and leave oxide of copper. The constituents of this salt, according to Vogel, are as follows:*

Oxalic acid	47·5
Ammonia	10·5
Peroxide of copper	25·0
Water	17·0
	100·00

If we consider it as a compound of 4 atoms acid, 2 atoms ammonia, 1 atom peroxide, and 6 atoms water, its constituents will be

Oxalic acid	44·86
Ammonia	11·18
Peroxide of copper	26·30
Water	17·66
	100·00

This subspecies, therefore, agrees in its constitution with the two last described salts. It is composed of 2 atoms of oxalate of ammonia, 1 atom of binoxalate of copper, and 6 atoms water.

(2.) *Efflorescing ammonio-oxalate.* If oxalate of copper be

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* Schweigger's Journal, vii. 25.

put into caustic ammonia and agitated till as much of it be dissolved as can be taken up by the cold liquid, and the liquid be then poured into a flat dish, it gradually deposits dark sky-blue crystals, composed of flat six-sided prisms, having two broad and four narrow faces. These crystals speedily effloresce when exposed to the air, and not only water but ammonia likewise is disengaged from it. The loss which it sustains by efflorescing is 18 per cent., and it loses no weight even when exposed to the heat of boiling water. According to the analysis of Vogel, assisted however by some calculation, the constituents of this salt are as follows:*

Oxalic acid	36·00
Ammonia	16·29
Peroxide of copper	39·00
Water	8·71
	100·00

If we consider it as composed of 2 atoms acid, 2 atoms ammonia, 1 atom peroxide, and 2 atoms water, its composition will be as follows:

Oxalic acid	35·35
Ammonia	16·65
Peroxide of copper	39·18
Water	8·82
	100·00

It is, therefore, a subsalt, and must be composed of 1 atom of oxalate of copper, 1 atom of suboxalate of ammonia, and 2 atoms of water.

(3.) *Pulverulent ammonio-oxalate.* If a greater quantity of oxalate of copper be put into caustic ammonia than the alkali is capable of dissolving, the oxalate of copper is gradually changed into a sandy powder, very similar in its appearance to smalt. This powder is the salt in question. It is not altered by exposure to the air, nor by a heat sufficient to deprive the first subspecies of its water of crystallization. When more strongly heated, the ammonia is driven off, and the residue burns with flame like the two preceding subspecies. Its constituents, as determined by Vogel by experiments, aided by a little calculation, are as follows:†

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* Schweigger's Journal, vii. 32.

† Ibid. 35.

Oxalic acid	43·00
Ammonia	9·72
Peroxide of copper	45·58
Water	1·70
	100·00

The water was probably only mechanically mixed with the salt. If we consider it as a compound of 2 atoms acid, 1 atom ammonia, and 1 atom peroxide, its composition will be as follows:

Oxalic acid	42·66
Ammonia	10·05
Peroxide of copper	47·29
	100·00

Composition.

This subspecies, therefore, is a neutral salt, composed of 1 atom oxalate of ammonia and 1 atom oxalate of copper. It may be worth while to give a synoptical view of the constitution of these three subspecies.

	1st subspecies.	2d subspecies.	3d subspecies.
Oxalic acid	4 atoms	2 atoms	2 atoms
Ammonia	2	2	1
Peroxide	1	1	1
Water	6	2	0
Number of atoms	13	7	4

Sp. 30. *Mellate of copper.* Mellitic acid, when dropped into acetate of copper, throws down a precipitate of a Spanish green colour, but produces no change on muriate of copper.*

31. Tartrate.

Sp. 31. *Tartrate of copper.* Tartaric acid has little action on copper, but it dissolves the metal at last by the assistance of the air, which converts it into an oxide, and the solution shoots into dark bluish-green crystals.† When this acid is poured into the sulphate or muriate of copper, it precipitates a tartrate of that metal in the form of blue crystals.‡

Sp. 32. *Tartrate of potash-and-copper.* This salt may be formed by boiling together oxide of copper and tartar in water. The solution yields by evaporation blue crystals, which have a sweetish taste, and contain a great proportion of metal.§

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* Klaproth's Beitrage, iii. 132.

† Grindel, Wenzel's Verwandtschaft der Korper, p. 214.

‡ Bergman, iii. 456.

§ Thenard, Ann. de Chim. xxxviii. 36.

Brunswick green.

When tartar and copper, or its oxides, are boiled together, they dissolve; and by evaporating to dryness, a bluish-green powder is obtained, which, according to Leonardi, constitutes the better kind of the pigment called *Brunswick green.*[*]

Sp. 33. *Citrate of copper.* Citric acid scarcely acts on copper; but it dissolves its oxide when assisted by a boiling heat, and the solution yields light green crystals.[†]

34. Formate.

Sp. 34. *Formate of copper.* This salt has a greenish-blue colour, and crystallizes in six-sided flat prisms terminated by a four-sided pyramid. They effloresce in the air, and become covered with a bluish-white powder. Their specific gravity is 1·815; 8·42 parts of cold water dissolve 1 part of these crystals. Spirit of wine (containing 86 per cent. of alcohol) dissolves $\frac{1}{400}$th of its weight of this salt, and acquires a light-blue colour. When heated, the crystals undergo the watery fusion. When the water is evaporated, the salt has a fine blue colour, and it does not begin to be decomposed till the heat is considerably increased. Then it is speedily decomposed, a liquid passes into the receiver, and metallic copper remains behind. One hundred grains of the crystals leave 28·5 grains of copper.[‡] Comparing this with the analysis of formic acid, by Berzelius, we may conclude that the salt is a compound of 2 atoms acid, 1 atom peroxide, and 8 atoms water. On that supposition its constituents will be

Formic acid	32·74
Peroxide of copper	35·39
Water	31·87
	100·00

Sp. 35. *Saclactate of copper.* Sulphate of copper is not precipitated by saclactic acid.[§]

Sp. 36. *Lactate of copper.* When lactic acid is digested on copper, it assumes first a blue colour, and then a green, which passes into a dark brown; but the solution does not crystallize.[‖]

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Such are the salts of copper, one of the most prolific of all the saline genera. There can be no doubt that the farther

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[*] Gren's Handbuch der Chemie, iii. 331.

[†] Wenzel's Verwandtschaft, p. 185.

[‡] Gehlen, Schweigger's Jour. iv. 14.

[§] Scheele, ii. 80.

[‖] Ibid p. 66.

researches of chemists will very much increase the number of the triple salts of copper. I have described eight species of them in this section, and I might have increased their number considerably, had I mentioned all that are known to exist, though their properties have not hitherto been examined.

The composition of the salts of copper is easily determined, by considering them as compounds of an atom of peroxide of copper and an atom of each of the acids. An atom of peroxide of copper weighs 10, and the weight of the acids has been given in a preceding chapter of this volume. The principal use to which the salts of copper have been applied is the formation of paints. The sulphate has been employed in dyeing, and the acetate forms an article which is employed in considerable quantity by the hat-makers.

SECT. XXIX.

SALTS OF BISMUTH.

The salts of bismuth have not been examined with much attention by chemists; indeed bismuth and its combinations have been hitherto very much neglected. These salts may be distinguished by the following properties:

Characters. 1. The solution of bismuth in acids is usually colourless. When water is poured into it, a white precipitate immediately falls, consisting chiefly of the white oxide of bismuth.

2. Ferrochyazate of potash occasions in these solutions a precipitate of a white colour, sometimes with a shade of yellow.

3. Hydrosulphuret of potash and sulphuretted hydrogen occasion a dark-brown precipitate.

4. Gallic acid and the infusion of nut-galls occasion a light-yellow precipitate.

5. When a plate of copper or tin is put into the solution of bismuth, this last metal is often precipitated in the metallic state.

1. Nitrate. Sp. 1. *Nitrate of bismuth.* Nitric acid, when concentrated, attacks bismuth with great violence, a vast quantity of nitrous gas is emitted, the metal is converted into a white oxide, much heat is evolved, and sometimes even sparks of fire, it is said, are darted out of the mixture. When the acid is diluted, the action is less violent, and the oxide of bismuth is dissolved as

it forms. The solution is colourless; and on cooling lets fall crystals of a white colour, and generally attached to each other in the form of stars. They are small four-sided prisms, often terminated by four-sided summits.

This salt, when exposed to the air, attracts a little moisture, and its surface is covered with a crust of white hydrated oxide. On burning coals it detonates feebly, emitting red sparks, and leaves a yellowish powder not easily reduced. When triturated with phosphorus it detonates loudly.* When put into water it is immediately decomposed; that liquid absorbing its acid, and leaving the white hydrated oxide of bismuth combined with a small portion of acid. Hence the reason, that when we write upon paper with a solution of bismuth in nitric acid, the characters, at first invisible, become white when the paper is plunged into water, as Brugnatelli first observed.†

When the solution of bismuth in nitric acid is diluted with water, the greatest part of the metal separates in the state of a subnitrate. In this state it was formerly known by the name of *magistery of bismuth*.

The paint called *pearl white*, frequently used as a cosmetic, is said to be precipitated from the nitrate of bismuth by means of common salt or tartar. Hence, in all probability, it is a submuriate or a tartrate of bismuth, according to circumstances.‡

According to the experiments of Lagerhjelm and Berzelius, the nitrate of bismuth is composed of

Nitric acid	34·2
Oxide of bismuth	48·8
Water	17·0
	100·0§

If we consider it as a compound of 1 atom acid, 1 atom oxide, and 3 atoms water, its composition will be

Acid	33·75
Oxide	49·37
Water	16·88
	100·00

Numbers which almost coincide with those obtained by experiments.

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* Brugnatelli, Ann. de Chim. xxviii. 73.

† Ibid. iii. 296.

‡ Black's Lectures, ii. 595.

§ Ann. de Chim. lxxxii. 122.

Sp. 2, 3. *Carbonate, borate.* The combinations which the oxide of bismuth forms with carbonic and boracic acids have not hitherto been examined with accuracy. They may be formed by pouring into the solution of bismuth in nitric acid the alkaline carbonates, or borates. The salts required precipitate in the state of a white powder.

4. Phosphate.

Sp. 4. *Phosphate of bismuth.* Phosphoric acid does not attack bismuth; but it combines with its oxide recently precipitated by an alkali. One portion of the salt formed remains in the state of an insoluble white powder; another portion is dissolved, and yields crystals, which do not deliquesce, and are soluble in water.* The white insoluble powder is most probably a subphosphate, and the crystals a superphosphate of bismuth.

5. Sulphate.

Sp. 5. *Sulphate of bismuth.* Sulphuric acid has no action on bismuth while cold; but by the assistance of heat it converts that metal into a white powder, while at the same time sulphurous acid is exhaled, and even sulphur sublimed, if the heat be considerable. When the saline mass, thus formed, is washed with water, two thirds of the acid are separated, carrying along with them a very small portion of the oxide; and this lixivium yields, by evaporation, small crystals in needles, which are decomposed, and their base precipitated when any attempt is made to dissolve them in water.

According to the experiments of Lagerhjelm the sulphate of bismuth is composed of 1 atom acid + 1 atom oxide, or by weight of

Sulphuric acid	100
Oxide of bismuth	197·5

The subsulphate formed by precipitating the sulphate by the addition of water, is composed, according to the experiments of Berzelius,† of 1 atom acid + 3 atoms oxide, or by weight of

Sulphuric acid	100
Oxide of bismuth	592·5

Sp. 6. *Sulphite of bismuth.* Sulphurous acid does not attack bismuth; but it combines with its oxide, and forms with it a salt insoluble in water even when assisted by an excess of acid. It has a sulphurous taste; and before the blow-pipe melts into a reddish-yellow mass, which is soon reduced upon charcoal.

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* Wenzel's Verwandtschaft, p. 177.

† Ann. de Chim. lxxxii. 241.

When distilled, the acid is driven off, and the whole oxide remains in a state of purity.*

7. Arseniate.

Sp. 7. *Arseniate of bismuth.* Arsenic acid oxidizes bismuth by a digesting heat; and the metal is covered with a white powder, which is arseniate of bismuth. Part also of the arseniate remains in solution, but the oxide is precipitated by the addition of water. The arseniate of bismuth precipitates when arsenic acid is poured into the nitrate of bismuth. The white powder thus obtained is difficultly fusible; but when heated with charcoal, arsenic sublimes, and the bismuth is reduced.†

Arseniate of bismuth is a white powder, often having a shade of green; it is tasteless, insoluble in water and nitric acid, but soluble in muriatic acid.‡ When heated upon charcoal, the smell of arsenic becomes perceptible. From the solution in muriatic acid, the bismuth is precipitated by sulphuretted hydrogen.

Sp. 8. *Molybdate of bismuth.* Molybdic acid precipitates muriate of bismuth white, provided there be no excess of acid.§

9. Acetate.

Sp. 9. *Acetate of bismuth.* Acetic acid has but little action on bismuth; but the acetate of bismuth may be obtained by mixing together the solutions of nitrate of bismuth and acetate of potash. When the mixture is heated, it redissolves the precipitate which had at first formed, and at the same time yields a number of thin talky crystals resembling boracic acid. Morveau, to whom we are indebted for this experiment, has ascertained also, that the addition of acetic acid, deprives nitrate of bismuth of the property of affording a precipitate when diluted with water.||

Sp. 10. *Benzoate of bismuth.* Benzoic acid dissolves the oxide of bismuth with facility; and the solution yields white needle-shaped crystals, which are not altered by exposure to the air, are soluble in water, and very sparingly soluble in alcohol. Sulphuric and muriatic acids decompose this salt, and heat volatilizes its acid.**

11. Succinate.

Sp. 11. *Succinate of bismuth.* Succinic acid does not attack bismuth; but it dissolves its oxide at a boiling temperature, and the solution yields yellow crystalline plates of succinate of bismuth. According to Wenzel, the solution of this salt in

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* Fourcroy, v. 204.

† Scheele, i. 84.

‡ Thenard, Ann. de Chim. l. 120.

§ Hatchett.

|| Encyc. Method. Chim. i. 10.

** Trommsdorff, Ann. de Chim. xi. 317.

Book II. Division II. water does not yield a precipitate with alkalies. It dissolves in nitric acid, and the solution is not precipitated by water.[*]

Sp. 12. *Oxalate of bismuth.* Oxalic acid scarcely attacks bismuth; but it combines with its oxide, and forms with it an oxalate in the state of a white powder, scarcely soluble in water. When oxalic acid is dropped into nitrate of bismuth, small transparent polygonal grains are gradually precipitated, which possess the same properties as the white powder, and do not become opaque when put into water.[†]

Sp. 13. *Tartrate of bismuth.* Tartaric acid does not attack bismuth; but when dropped into the solution of that metal in sulphuric, nitric, or muriatic acids, tartrate of bismuth precipitates in the state of a white crystalline powder insoluble in water.[‡]

SECT. XXX.

SALTS OF MERCURY.

There is no genus of metallic salts which has been subjected to a longer or more varied examination than this. Mercury was the metal from which the alchymists conceived the greatest hopes, and which they exposed to every possible torture during their researches after the philosopher's stone. The introduction of mercurial salts into medicine occasioned a scrutiny no less varied than obstinate, after the paroxysm of the alchymists was over. The important cures performed by their means, especially in cases of the venereal disease, were early seen by physicians: but the energy with which they acted, and the ravages which they sometimes made on the constitutions of those who used them, were equally visible. These deleterious effects were ascribed to a certain acrid *something* which was supposed to constitute a component part of mercury. The object of chemical physicians was long directed towards discovering a method of removing, neutralizing, or destroying this acrid something, without impairing the good effects of the medicine. Hence the numerous preparations of mercury which were one after another introduced into practice; some of which have in a great measure answered the purposes for which they were intended; while the

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[*] Wenzel's Verwandtschaft, p. 243.

[†] Bergman, i. 261.

[‡] Gren's Handbuch, iii. 300.

greater number, after continuing fashionable for a time, have gone one after another out of use.

Mercurial salts have lately engaged the attention of philosophical chemists, because, from the peculiar nature of the metal, the changes which take place during their formation are more easily traced. To them we are indebted for the discovery of the composition of sulphuric acid, of metallic oxides, and for the first decisive proofs of the non-existence of phlogiston; to them we owe the discovery of oxygen gas, and perhaps also of nitrous gas.

Mercurial salts are distinguished by the following properties.

Characters.

1. When strongly heated, they are volatilized and dissipated; and traces of mercury may sometimes be observed.

2. Ferrochyazate of potash occasions a whitish precipitate, which becomes yellow when exposed to the air.

3. Hydrosulphuret of potash occasions a black precipitate.

4. Muriatic acid, when poured into their solution in water, often occasions a white precipitate.

5. Gallic acid, or the infusion of nutgalls, occasions an orange-yellow precipitate.

6. A plate of copper plunged into a liquid mercurial salt gradually precipitates running mercury.

There are two oxides of mercury, and most acids seem capable of combining with both. Of course every species is divisible into two subspecies: protosalts and persalts. Many of these subspecies are capable of existing in the state of *sub* and *super* salts. This gives rise to another set of varieties still more numerous.

The oxides of mercury are thrown down from their solution in acids by most of the alkalies and alkaline earths, but in different states. When lime is used, Proust has shown that a portion of the acid is retained, and that the precipitate combines with about $\frac{1}{100}$th part of its weight of lime. When ammonia is used, Bayen has ascertained that the precipitate retains a considerable portion of that alkali. But from Berthollet's experiments we learn that the fixed alkalies throw down a subsalt of mercury not contaminated with any of the precipitating body.

Sp. 1. *Nitrate of mercury.* Though the action of nitric acid on mercury has been long familiar to chemists, yet the first person who accurately determined the nature of the salts formed was Mr. Donovan. Nitric acid dissolves pure mercury with facility, either with or without the assistance of heat. The concentrated solution gradually deposits white coloured crystals, which always consist of pure *protonitrate* of mercury. These crystals are octahedrons, all the solid angles of which are usually truncated. They have a strong mercurial taste, and act with great energy on the system. When exposed to the air they gradually lose a portion of their acid and become yellow. Water produces the same effect by depriving them likewise of part of their acid. In water, acidulated with nitric acid, they dissolve, and the solution is colourless. When washed with hot water a blue-grey deposit falls from the water, which is the *subprotonitrate of mercury.* The yellow powder contains a greater proportion of acid. When this salt is heated the acid is decomposed, and the mercury converted into peroxide. The mercury is precipitated in the metallic state from solutions of this salt by sulphuretted hydrogen and by protomuriate of tin.

Pernitrate of mercury may be obtained by dissolving peroxide of mercury in nitric acid and evaporating to dryness. A white crystalline mass remains, which deliquesces on exposure to the air, but not to perfect liquidity. This salt does not crystallize regularly. It is more acrid than protonitrate. It always remains in solution after the protonitrate of mercury has crystallized. When water is poured upon the dry salt a decomposition takes place, supernitrate of mercury dissolves, and subpernitrate remains behind in the state of an insoluble brown powder.*

2. Carbonate.

Sp. 2. *Carbonate of mercury.* Carbonic acid does not attack mercury, but it may be combined with its oxide by pouring an alkaline carbonate into nitrate of mercury. The precipitate in that case is a white powder, composed, according to Bergman, of

90·9	mercury
9·1	oxygen and acid
100·0†	

Supposing the carbonate a compound of 1 atom carbonic acid + 1 atom peroxide of mercury, it will consist of

Carbonic acid	9·24
Peroxide	90·76
	100·00

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* Annals of Philosophy, xiv. 246.

† Bergman, ii. 391.

3. Borate.

Sp. 3. *Borate of mercury.* Boracic acid has no action on mercury; but borate of soda, poured into a solution of that metal in nitric acid, occasions a precipitate of borate of mercury in the state of a yellow powder, first described by Monnet. Its specific gravity is 2·266.*

4. Phosphate.

Sp. 4. *Phosphate of mercury.* Phosphoric acid does not act on mercury; but it combines with its oxide, and forms phosphate of mercury. This salt is formed most conveniently by mixing together the solutions of nitrate of mercury and phosphate of soda. The salt immediately precipitates in the state of a white powder. This salt has been lately introduced into medicine, and seems to answer equally well with the other mercurial preparations. It phosphoresces when rubbed in the dark; and when distilled, it yields phosphorus, like the other metallic phosphates. Its specific gravity is 4·9835.† This salt is in fact a perphosphate of mercury. Its constituents, according to Braamcamp and Sequiera Oliva, are

28·5 acid
71·5 peroxide

100·0 ‡

Sp. 5. *Phosphite of mercury.* Messrs. Braamcamp and Sequiera Oliva have shown, that phosphorous acid decomposes all the oxides and salts of mercury, separating the base in the metallic state. Hence it is not probable that phosphite of mercury can exist.§

Sp. 6. *Sulphate of mercury.* Of this, like most other salts of mercury, there are two subspecies.

(1.) *Protosulphate of mercury.* It is formed when strong sulphuric acid is heated on mercury so gently that the mixture barely effervesces. A white salt gradually precipitates, which is the protosulphate. It has a strong mercurial taste, and is very sparingly soluble in sulphuric acid. Water decomposes it.

When protoxide of mercury and sulphuric acid are triturated together, its colour changes to grey, but it does not dissolve. This powder when properly edulcorated, is a subprotosulphate of mercury. When digested in boiling water it becomes greenish grey. The addition of sulphuric acid restores

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* Hassenfratz, Ann. de Chim. xxviii. 12.

† Ibid.

‡ Braamcamp and Sequiera Oliva, Ann. de Chim liv. 125.

§ Ann. de Chim. liv. 125.

the original colour, or even renders it white by converting it into a neutral salt.

(2.) *Persulphate* may be formed by boiling mercury violently, and for a considerable time in concentrated sulphuric acid. The protosulphate at first formed is gradually changed into persulphate. If we treat in this way 2 parts of mercury and 3 of strong acid, the whole salt formed is persulphate. Its colour is a dirty white. Like the protosulphate, it is decomposed by water being deprived of the excess of acid which it contained and converted into a fine yellow powder, which seems to be a neutral persulphate.[*] It was known formerly by the name of *turpeth mineral.* Its specific gravity is 6·444.[†] It is soluble in 2000 parts of cold water, and in 600 parts of boiling water. The solution is colourless.[‡]

Turpeth mineral.

The name *turpeth mineral* seems to have been given to this salt by Crollius, who boasted of its medicinal virtues, but kept the preparation a secret. He attempted to moderate the violent action of this substance by a long digestion, but without success. The process for preparing it was afterwards made public. Kunkel published a set of experiments on it in 1700, in his *Laboratorium Chymicum.* The name *turpeth* was no doubt given from some resemblance which it was supposed to have either in its colour or effects to the root of the *convolvulus turpethum*, a plant formerly used in medicine.

According to the experiments of the Portuguese chemists above quoted, *turpeth mineral* is composed of

15·0	acid
84·7	peroxide
0·3	water
100·0[§]	

Supposing it a compound of 1 atom acid + 1 atom peroxide, its constituents will be

Sulphuric acid	15·62
Peroxide	84·38
	100·00

Numbers which agree sufficiently with the preceding ana-

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[*] Donovan, Annals of Philosophy, xiv. 321.

[†] Watson's Chemical Essays, v. 68.

[‡] Fourcroy, Ann. de Chim. x. 208.

[§] Ann. de Chim. liv. 123.

lysis to show that our notion respecting the constitution of this salt is correct.

Sp. 7. *Hyposulphite of mercury*. From the experiments of Mr. Herschell, there is reason to believe that this salt does not exist.*

Sp. 8. *Seleniate of mercury*. Of this salt likewise there are two subspecies.

(1.) *Protoseleniate*. A white insoluble powder obtained by pouring selenic acid into a protosalt of mercury. When heated it melts, and forms a mass of a deep brown colour. When cold, the colour becomes lemon yellow. When more strongly heated, it may be distilled over in amber coloured drops, usually transparent. It is decomposed by potash, and likewise by muriatic acid.

(2.) *Perseleniate* is obtained by saturating selenic acid with peroxide of mercury. It is a white powder nearly insoluble in water. When only a certain portion of oxide is dissolved in the acid, if we filter and evaporate, we obtain large prismatic crystals, striated longitudinally. These are *biperseleniate* of mercury. This salt dissolves sparingly in alcohol. It melts when heated in its water of crystallization. The anhydrous salt does not melt, but sublimes without alteration.†

Sp. 9. *Arseniate of mercury*. When arsenic acid and mercury are heated in a retort, white oxide of arsenic, mercury, and oxide of mercury of a yellow colour, are driven over, and there remains a yellow-coloured insoluble mass, consisting of arseniate of mercury. The same salt is precipitated in the form of a yellow powder when arsenic acid is poured into the liquid nitrate or sulphate of mercury.‡

Sp. 10. *Chromate of mercury*. This salt may be formed by mixing together the solutions of an alkaline chromate and a mercurial nitrate. It is an insoluble powder of a fine purple colour.§

Sp. 11. *Molybdate of mercury*. Molybdic acid precipitates mercury from nitric acid in the form of a white flaky powder; ‖ but it occasions no precipitate in the solution of corrosive sublimate.**

Sp. 12. *Tungstate of mercury*. Tungstic acid forms with

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* Edin. Phil. Jour. i. 28.

† Berzelius; Ann. de Chim. et de Phys. ix. 342.

‡ Bergman, ii. 391.

§ Vauquelin.

‖ Hatchett.

** Scheele, i. 247.

the oxide of mercury an insoluble powder, which has not been examined.

13. Acetate. Sp. 13. *Acetate of mercury.* Acetic acid does not act sensibly on mercury; but it dissolves its oxides, especially when hot. The first accurate set of experiments on these solutions was made by Margraff, who procured from them a salt in crystals.[*] With the protoxide of mercury acetic acid forms an *acetate*, and with the red oxide a *peracetate;* salts which were first properly distinguished from each other by Mr. Proust.[†]

1. *Acetate of mercury.* This salt may be formed by dissolving in acetic acid the precipitate obtained from nitrate of mercury by means of alkalies. As the solution cools, thin brilliant plates of acetate of mercury are deposited, resembling boracic acid. It may be prepared also by mixing together solutions of nitrate of mercury and acetate of potash. Large flat crystals of acetate of mercury, of a silvery whiteness, soon make their appearance. This salt has an acrid taste, is insoluble in alcohol, and soluble in 600 times its weight of water.[‡] In alkalies it blackens. The proportion of the constituents of this salt has not been ascertained. It is employed in medicine.

Crystals.

2. *Peracetate of mercury.* This salt is obtained by dissolving the red oxide of mercury in acetic acid. It does not crystallize; but when evaporated to dryness, forms a yellow mass, which soon deliquesces. It dissolves readily in alcohol: but water divides it into two salts; a *superacetate*, which remains dissolved in the water, in consequence of its great excess of acid; and a *subperacetate*, in the same state of a yellow powder, insoluble in water. When the solution of red oxide of mercury in acetic acid is heated, some crystals of acetate are obtained; because a part of the oxygen of the oxide is separated at the expense of the acid, a portion of which is decomposed.[§]

Varieties.

14. Benzoate. Sp. 14. *Benzoate of mercury.* Benzoic acid dissolves the oxide of mercury, and forms with it a white powder, not altered by exposure to the air. It is insoluble in water, and very sparingly soluble in alcohol. A moderate heat sublimes this salt, and a strong heat decomposes it. It is decomposed by lime, by sulphuric acid, and muriatic acid, and by sulphur.[||]

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[*] Opusc. i. 119.

[†] Jour. de Phys. lvi. 205.

[‡] Braconnot, Ann. de Chim. lxxxvi. 92.

[§] Proust, Jour. de Phys. lvi. 205.

[||] Trommsdorf, Ann. de Chim. xi. 316.

Sp. 15. *Succinate of mercury.* When succinic acid is digested with the oxide of mercury, it forms with it a shapeless mass containing some crystals, and soluble in water; from which the oxide is precipitated by alkalies and hydrosulphurets.[*] These crystals, I conceive, are bisuccinate of mercury. When succinate of ammonia is dropped into corrosive sublimate, an insoluble white precipitate falls, which is persuccinate of mercury.

16. Oxalate.

Sp. 16. *Oxalate of mercury.* Oxalic acid does not act on mercury; but it dissolves its oxide, and forms with it an oxalate in the state of a white powder, scarcely soluble in water. When exposed to the light, it very soon becomes black. The same salt is precipitated when oxalic acid is poured into the sulphate or nitrate of mercury.[†] Klaproth first discovered that this salt has the property of detonating when heated:[‡] the same observation was afterwards made by Von Packen.[§] Howard's fulminating powder consists partly of this salt.

Sp. 17. *Mellate of mercury.* Mellitic acid occasions a white precipitate in nitrate of mercury, which is redissolved on the addition of nitric acid.[||]

18. Tartrate.

Sp. 18. *Tartrate of mercury.* Tartaric acid does not attack mercury; but it dissolves its protoxide, and forms with it an insoluble white salt, which soon becomes yellow when exposed to the light. This salt precipitates also when tartaric acid is poured into nitrate of mercury.

Sp. 19. *Tartrate of potash-and-mercury.* This salt, first described by Monnet, may be formed by boiling in water six parts of tartar and one part of oxide of mercury. The liquid, when evaporated, yields small crystals of tartrate of potash-and-mercury. Thenard has ascertained, that the same triple salt may be formed by mixing together the solutions of tartar and mercurial nitrate. This salt is decomposed by the alkalies, the alkaline carbonates, the hydrosulphurets, the sulphates, and the muriates.[**]

20. Citrate.

Sp. 20. *Citrate of mercury.* This salt has been examined by Vauquelin. Citric acid does not attack mercury; but when poured upon its red oxide, an effervescence takes place, and the oxide becomes white and unites into one mass. The ci-

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[*] Wenzel's Verwandtschaft, p. 245.

[†] Bergman, i. 266.

[‡] Westrumb's Kl. Ph. Chim. Abb. i. 228.

[§] De Sale Acid. Tartari, 1779.

[||] Klaproth's Beitrage, iii. 131.

[**] Ann. de Chim. xxxviii. 30.

trate thus formed has a mercurial taste, but is scarcely soluble in water. Nitric acid decomposes it. When distilled, there comes over acetic and carbonic acids, and the mercury is reduced.*

Sp. 21 and 22. *Saclactate and malate of mercury.* When saclactic acid or malic acid is dropped into nitrate of mercury, a white precipitate appears.†

23. Lactate.

Sp. 23. *Lactate of mercury.* Lactic acid dissolves both oxides of mercury. With the protoxide it forms a light yellow coloured matter which becomes white by repeated solution and evaporation. It contains an excess of acid, deliquesces in the air, and is partly dissolved in alcohol. But at the same time the salt is decomposed. With the peroxide it forms a red gummy deliquescent salt. If left exposed in a warm and moist place it deposites a light semicrystalline powder, which Berzelius conjectures to be acetate of mercury.‡

Such are the properties of the salts of mercury as far as they have been examined. A greater number of them are insoluble in water than of the salts of any other genus. Their composition may be easily determined by considering them as compounds of 1 atom oxide of mercury and 1 atom of each of the acids. The weight of an atom of protoxide of mercury is 26, of that of peroxide 27, and the weight of the different acids has been given in a preceding chapter of this volume.

Several of the mercurial salts have been introduced into medicine, and some, as *turpeth mineral*, constitute beautiful paints. They are well entitled to a more accurate examination than has been hitherto bestowed upon them.

SECT. XXXI.

SALTS OF SILVER.

Several of the acids are capable of oxidizing silver; but it resists the action of the greater number. The nitric dissolves it with great facility; hence it is the nitrate of silver with

* Fourcroy, vii. 209.

† Scheele, ii. 80, and Crell's Annals, ii. 11. Eng. Trans.

‡ Berzelius, Djurkemien, ii. 438.

which we are best acquainted. Most of the other acids form with it compounds scarcely soluble in water. The salts of silver may be easily ascertained by the following properties:

Characters.

1. When exposed to the action of the blow-pipe upon charcoal, they are reduced, and a globule of silver obtained.

2. Ferrochyazate of potash, when dropped into a solution of a salt of silver, occasions a white precipitate.

3. Hydrosulphuret of potash occasions a black precipitate.

4. Muriatic acid of the alkaline muriates occasion a white heavy flaky precipitate resembling curd.

5. Gallic acid and the infusion of nutgalls occasion a yellowish brown precipitate, at least in several of the solutions of silver.

6. When a plate of copper is put into a solution of silver, that last metal is precipitated in the metallic state, retaining, however, a little of the copper alloyed with it.

7. The solution of sulphate of iron precipitates the silver in the metallic state.

1. Nitrate.

Sp. 1. *Nitrate of silver.* Nitric acid attacks silver with considerable violence, and dissolves about half its weight of it. The effervescence is occasioned by the disengagement of nitrous gas. The acid employed must be pure; if it contains any muriatic acid, as is always the case with the nitrous acid of commerce, a white insoluble chloride of silver falls to the bottom of the vessel. If the silver contain gold, that metal is also precipitated in the form of a black or very deep purple powder.

Properties.

The solution is limpid and colourless, exceedingly heavy, and caustic. It gives the skin, hair, and almost all animal substances, an indelible black colour. Hence it is often used to dye hair, &c. When evaporated till a pellicle begins to form on its surface, it deposites, on cooling, transparent crystals of nitrate of silver. These crystals are brilliant and very irregular; sometimes assuming the form of six-sided, sometimes of four-sided, and sometimes of three-sided, thin plates. Their taste is intensely bitter and metallic.

This salt, at the temperature of 60°, dissolves in its own weight of water.* It does not deliquesce in the air; but when exposed to a strong light, it becomes brown, and the silver is partly reduced. It is soluble in alcohol.† It crystallizes in

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* Wenzel, Verwandtschaft, p, 308.

† Kunkel, Phil. Trans. 1681, vol. xv. 896.

flat rhomboids with angles of 120° and 60°. One edge of the rhomboid is nearly twice as long as the other. When heated, it readily melts, swells up, and then remains liquid. When allowed to cool, it forms a grey-coloured mass, crystallized internally in needles. In that state it is cast in moulds by apothecaries, and formed into small cylinders, often employed by surgeons under the names of *lapis infernalis* and *lunar caustic*, to open ulcers and destroy fungous excrescences. Its specific gravity is 3·521.

Lunar caustic.

When this salt is exposed to a red heat, as when it is put upon burning coals, it detonates, and the silver remains pure, attached to the surface of the coal. The same reduction takes place when the salt is distilled in a retort, and nitrous gas, oxygen gas, and azotic gas are disengaged.

Action of combustibles.

Mrs. Fulhame has shown, that when this salt is dissolved in water, it is decomposed, and the silver reduced by means of hydrogen gas and phosphorus. A bit of silk moistened with this solution, and exposed to the action of hydrogen gas, is almost immediately covered with a thin layer of silver, which adheres strongly. The same effect is produced by phosphorus and by sulphurous acid gas.

This salt, both in crystals and after being melted, has the property of fulminating violently when mixed with phosphorus, and struck smartly with a hammer. This was first observed by Brugnatelli. To the same ingenious chemist we are indebted for the two following facts. When three grains of sulphur and nine grains of nitrate of silver, mixed together, are struck with a cold hammer, the sulphur inflames, but no detonation takes place; whereas if the hammer be hot, the mixture detonates, and the silver is reduced. If charcoal be substituted for sulphur, only a faint detonation is heard though the hammer be hot.*

The silver is precipitated from the solution of this salt in water in a metallic state by the greater number of the metals, especially by mercury and copper, which at the same time combine with it.

This salt is decomposed by all the alkalies and alkaline earths, and by the sulphuric, sulphurous, muriatic, phosphoric, fluoric acids, and their salts.

Mr. Proust has shown, that when silver is dissolved in nitric acid a small portion of the metal is volatilized by the ebul-

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* Ann. de Chim. xxvii. 72.

lition. From his experiments it does not appear that nitrate of silver contains any water of crystallization. He found it composed of

69	or 70	oxide of silver
31	30	nitric acid
100	100*	

Its true composition is as follows:

1 atom nitric acid ...... =	6·75	31·39	100
1 atom oxide of silver .. =	14·75	68·61	218·52
		100·00	

Gay-Lussac has shown that pure silver may be obtained by precipitating nitrate of silver by copper, and digesting the precipitate in a weak solution of nitrate of silver. By this digestion the copper is dissolved and silver precipitated in its place.†

2. Nitrite.

Sp. 2. *Nitrite of silver.* This salt may be obtained by the following process: Put a quantity of pure powder of silver into a solution of nitric acid already saturated with silver, and boil the mixture for an hour after nitrous gas has ceased to be evolved; then draw off the clear liquor with a bulbed siphon. The solution is of a pale yellow colour, and it may be concentrated much more than the solution of nitrate, as the nitrite which it affords is much more soluble. When it is in the proportion of 240 to 100 of water, it is still far enough from crystallizing, and sometimes it remains fluid for several days; but if it be poured into a phial, it congeals so suddenly, that the last portions from the mouth of the retort become solid like icicles from the eaves of a house, and a great deal of heat is evolved. It is difficult to bring it to a regular crystallization, because it has a much greater tendency to congeal than to separate into crystals. If it congeal, it cannot be redissolved without the separation of a yellow powder, which is a subnitrite of silver. Hence it appears that the portion dissolved takes a portion of acid from this yellow powder.

When the solution of nitrite of silver is kept in the open air, it soon absorbs oxygen, loses its colour, and deposites crystals of nitrate. The same change is produced immediately by the addition of nitric acid. Hence a few drops of that acid occasion the immediate deposition of large scales of nitrate.

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* Nicholson's Jour. xv. 375.

† Ann. de Chim. lxxviii. 91.

When the solution of nitrite of silver is mixed with the infusion of litmus, a blue lake precipitates. Nitrate produces no effect upon this infusion. From the solution of cochineal the nitrite throws down a deep violet lake; the nitrate produces a scarlet powder. When the nitrate is dropped into sulphate of indigo, no change is produced; the nitrite instantly deprives it of colour, while the silver is reduced. Ammonia precipitates a black powder from the nitrite of silver. This black powder is silver reduced. What is dissolved by the ammonia is in the state of nitrate. Pure potash throws down a brown precipitate, as it does from nitrate. Alcohol acts on nitrite of silver precisely as water does. A portion of subnitrite precipitates, and a supernitrite is dissolved. If the alcoholic solution be distilled, it leaves behind a portion of nitrate and of silver reduced. When a little nitrite of silver is dropped into boiling water, it is decomposed, a portion of the silver is reduced, and precipitated in the state of a black powder, and the rest of the salt is converted into nitrate.

When the nitrite of silver is concentrated in a retort, it grows thick, gives out a little nitrous gas, enters into fusion, and affords a yellow sublimate which lines the sides of the retort. If the melted mass be dissolved, a yellow powder mixed with a little reduced silver precipitates.*

3. Carbonate.

Sp. 3. *Carbonate of silver.* Carbonic acid has no action whatever upon silver; but it is absorbed readily by the oxide of that metal. The carbonate may be obtained by precipitating silver from its acid solutions by means of a carbonated alkali. A white insoluble powder is obtained, which is carbonate of silver. This salt becomes black when exposed to the light; and, when heated, the acid is driven off, and the silver reduced. According to Bergman, when this salt is obtained by precipitating 100 parts of silver from its solution, by means of carbonate of soda, it weighs 129.† Its constituents must be

1 atom carbonic acid ..	2·75	15·71
1 atom oxide of silver ..	14·75	84·29
		100·00

4. Borate.

Sp. 4. *Borate of silver.* Boracic acid has no action on silver whatever; but the borate may be formed by pouring a solution of borax into liquid nitrate of silver. The salt falls to

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* Proust, Nicholson's Jour. xv. 376.

† Bergman, ii, 391.

the bottom in the form of an insoluble white powder, which has not been examined.

5. Phosphate.

Sp. 5. *Phosphate of silver.* Phosphoric acid does not act upon silver, but it combines readily with its oxide. Phosphate of silver is precipitated in the state of a yellow powder when phosphoric acid is poured into liquid nitrate of silver. It is insoluble in water, but soluble in an excess of phosphoric acid. When heated strongly in a crucible, a little phosphorus comes over, and phosphuret of silver remains in the retort.* This salt is soluble in nitric acid.† Mr. Chenevix has shown, that when boiled with a solution of an earthy muriate in proper proportions, chloride of silver and phosphate of the earth, both insoluble, are formed, so that the liquid is deprived of the whole of its saline part.

Berzelius when he mixed a solution of phosphate of soda with nitrate of silver, obtained a sesquiphosphate in the state of an insoluble yellow powder, and destitute of water of crystallization. It was composed of 1 atom phosphoric acid, and 1½ atom of oxide of silver, or, which comes to the same thing, of 2 atoms acid, and 3 atoms oxide. The following table exhibits its constituents:

	‡	§
Acid	17·025	16·9
Base	82·975	83·1
	100·000	100·0

6. Sulphate.

Sp. 6. *Sulphate of silver.* Sulphuric acid does not act on silver while cold; but when boiled upon that metal in the state of powder an effervescence is produced, occasioned by the escape of sulphurous acid gas, and the silver is reduced to a white mass soluble in diluted sulphuric acid. This solution is limpid and colourless, and yields on evaporation crystals of sulphate of silver. These crystals are white and brilliant, and have the form of very fine prisms.

Properties.

This salt, according to Wenzel, requires 87¼th parts of water to dissolve it: hence the reason that it is generally precipitated in the state of a white powder when sulphuric acid is dropped into a solution containing silver. It is soluble in nitric acid without decomposition.‖ When heated, it melts, and in a red

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* Fourcroy, vi. 340.

† Darracq, Ann. de Chim. xl. 178.

‡ Berzelius, Ann. de Chim. et Phys. ii. 163.

§ Theoretical composition.

‖ Klaproth.

heat is decomposed: the silver is reduced, and sulphurous acid and oxygen gas are disengaged. When exposed to the light, it is slowly decomposed. It is decomposed also by the following bodies:

1. Alkalies and alkaline earths, and their carbonates.
2. Muriates, phosphates, fluates.

According to Bergman,* 100 parts of silver, precipitated from its solution by sulphuric acid, yield 134 of sulphate. It is obvious that it must be composed of

1 atom acid = 5 ...... 25·31
1 atom oxide = 14·75 ...... 74·69

100·00

7. Sulphite.

Sp. 7. *Sulphite of silver.* Sulphurous acid does not attack silver, but it combines readily with its oxide. The sulphite assumes the form of small brilliant white grains. It has an acrid metallic taste. Water dissolves only a very minute portion of it: accordingly sulphurous acid occasions a white precipitate of sulphite in solutions of silver. When exposed to the light, it assumes a brown colour. When strongly heated the silver is reduced, and sulphurous and sulphuric acids exhaled.

This salt may be obtained also by mixing together the solutions of sulphite of ammonia and nitrate of silver; but if too much sulphite of ammonia be added, the salt is redissolved, and a triple salt formed, composed of sulphurous acid, oxide of silver, and ammonia. The fixed alkalies are also capable of dissolving the sulphite of silver, and forming with it triple salts.†

Sp. 8. *Hyposulphite of silver.* When nitrate of silver is dropped into any hyposulphite sufficiently diluted, a white cloud appears, which is redissolved by agitation: on continuing the addition of nitrate of silver the cloud reappears and aggregates into a dirty grey flaky precipitate, which is hyposulphite of silver. This salt is soluble in water, and has an intensely sweet taste. Its solution is not precipitable by a muriate. When kept it gradually undergoes decomposition, and is at last coverted into sulphuret of silver.‡

All the hyposulphites are capable of dissolving chloride of

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* Opusc. ii. 391.

† Fourcroy, vi. 323.

‡ Herschell, Edin. Phil. Jour. i. 26.

silver. The solution has a sweet taste, and seems therefore to consist of hyposulphite of silver probably united to the base of the hyposulphite employed. Of these double salts Mr. Herschell has examined the following.

Sp. 9. *Hyposulphite of potash-and-silver.* When potash is dropped into a solution of chloride of silver in hyposulphite of soda, a copious precipitate falls, consisting of small pearly scales similar in appearance to boracic acid. These scales are the hyposulphite of potash-and-silver. They have an intensely sweet taste, and before the blow-pipe blacken, melt, and yield a bead of silver in the midst of a saline mass which spreads on the charcoal. The same precipitate is produced by the carbonate, nitrate, sulphate, and probably by all the salts of potash. Hence Mr. Herschell proposes the solution of chloride of silver in hyposulphite of soda as a useful test for distinguishing potash from soda.

Sp. 10. *Hyposulphite of soda-and-silver.* This salt is obtained by dissolving chloride of silver in hyposulphite of soda, and evaporating the solution gently. It crystallizes in thin silky plates, which have an intensely sweet taste, and are readily soluble in water.

Sp. 11. *Hyphosulphite of ammonia-and-silver.* This salt is obtained by dissolving chloride of silver in hyposulphite of ammonia, and mixing alcohol with the solution. It is a white salt, very soluble in water, and having an intensely sweet taste. One grain of it communicates a sensible sweetness to 32,000 grains of water. By evaporating the alcoholic solution the same salt is sometimes obtained in thin lengthened hexangular plates. This salt, according to the analysis of Herschell, is composed of

2 atoms hyposulphite of ammonia
1 atom hyposulphite of silver.

After the hyposulphite of ammonia refuses to dissolve any more chloride of silver, if an additional quantity be added, it is rapidly converted into a white crystallized powder. This powder is scarcely soluble in water, but dissolves readily in ammonia, forming an intensely sweet solution, from which an acid throws it down unaltered. Mr. Herschell considers it as a compound of

1 atom hyposulphite of ammonia
1 atom hyposulphite of silver.

Sp. 12. *Hyposulphite of lime-and-silver.* This salt is obtained by dissolving chloride of silver in hyposulphite of lime, and mixing the solution with a considerable quantity of alcohol. It is a white salt of an intensely sweet taste, and soluble in water. It is decomposed by a moderate heat.

When more chloride of silver is added to hyposulphite of lime than can be dissolved, the additional portion is converted into a voluminous crystalline powder, of very difficult solubility in water, but abundantly soluble in ammonia, and giving that liquid an intensely sweet taste. Mr. Herschell considers it as a compound of

1 atom hyposulphite of lime
1 atom hyposulphite of silver.

Sp. 13. *Hyposulphite of strontian-and-silver.* This salt is formed by the action of hyposulphite of strontian on chloride of silver. It is nearly tasteless and insoluble in water; but dissolves readily in ammonia and gives to that liquid an intensely sweet taste.*

Sp. 14. *Seleniate of silver.* This salt is precipitated in the state of a white powder by dropping selenic acid into a solution of nitrate of silver. Boiling water dissolves a little of it. It dissolves completely in boiling nitric acid; but is precipitated again when the acid is diluted with water. If a boiling solution of this salt in nitric acid be mixed with boiling water, the seleniate falls down in needles as the solution cools. This salt is not blackened by exposure to the light. When heated it melts and becomes transparent like chloride of silver. On cooling it is converted into a white, opaque, friable mass, the fracture of which exhibits a crystallized texture. When strongly heated and exposed to a current of air, selenic acid and oxygen gas are disengaged, and it becomes covered with a pellicle of metallic silver. This salt, according to Berzelius, is composed of

Selenic acid	100
Oxide of silver	205·75 †

15. Arseniate.

Sp. 15. *Arseniate of silver.* For the only account of this salt hitherto given we are indebted to Scheele, the discoverer of arsenic acid. This acid does not attack silver at the common temperature; but when the two bodies are heated to-

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* Edin. Phil. Jour. i. 27 and 398.

† Ann. de Chim. et de Phys. ix. 343.

gether pretty strongly, arsenic is sublimed, the silver oxidized, and the mixture melts into a transparent glass. Water carries off from this glass arsenic acid, holding silver in solution, and leaves a brown insoluble powder, which is arseniate of silver. When this salt is exposed to a heat sufficient to melt the silver, that metal is reduced.

The arseniate of silver may be obtained also by dropping arsenic acid into a solution of silver in nitric acid. The salt precipitates in the state of a flesh-red powder, which becomes brown when dry. It may be obtained equally by using, instead of arsenic acid, the alkaline arseniates.*

Scheele has observed, that a mixture of arsenic and muriatic acids dissolves silver in a digesting heat, and converts it into chloride, though neither of these acids has any effect on it separately. During the process the arsenic acid loses its oxygen, and is converted into arsenic.†

Sp. 16. *Arsenite of silver.* This salt has been examined by Dr. Marcet, in consequence of his application of it as a test for the discovery of arsenious acid.‡ It may be obtained by dropping nitrate of silver into a solution containing arsenious acid. An orpiment yellow precipitate appears, which is the salt in question. After some time it becomes brown, and this is the colour which it retains when dry. It is insoluble in water, but dissolves readily in diluted nitric acid. If an excess of ammonia be added just after its formation, it is re-dissolved. But the dry salt is insoluble in ammonia. When heated in a glass tube a white smoke evaporates, which condenses on the sides of the tube in minute octahedral crystals of arsenious acid, while a dark-brown mass remains, which is an arsenite. Before the blow-pipe upon platinum, and still better upon charcoal, the silver is reduced, and the arsenic dissipated.§

Sp. 17. *Chromate of silver.* This salt may be formed by mixing solutions of chromate of potash and nitrate of silver. The precipitate is reddish-brown when the liquids are mixed hot; purple red when they are mixed cold, and carmine red when the chromate of potash contains an excess of acid. It becomes brown when exposed to the light, and is soluble in nitric acid.‖ 17. Chromate.

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* Scheele, i. 167.

† Ibid. p. 169.

‡ Mr. Hume first proposed nitrate of silver as a mode of detecting small quantities of arsenious acid. But the use of this test was materially improved by the experiments of Dr. Marcet and Dr. Paris.

§ Annals of Philosophy, iii. 236.

‖ Vauquelin, Ann. de Chim. lxx. 70.

Sp. 18. *Molybdate of silver.* When molybdic acid is added to a nitrate of silver, a white flaky precipitate falls.*

19. Acetate.

Sp. 19. *Acetate of silver.* Acetic acid has no action whatever on silver, but it readily dissolves its oxide, and forms with it acetate of silver. It may be formed easily by putting acetate of potash into a solution of nitrate of silver, or by saturating hot acetic acid with the oxide of silver. On cooling, the solution yields, according to Margraff, small needle-form crystals of an acrid metallic taste, and easily dissolved in water.† When heated, it swells up, the acid is dissipated, and the oxide of silver remains behind.

Sp. 20. *Benzoate of silver.* Benzoic acid does not attack silver, but it dissolves its oxide, and forms with it a salt easily soluble in water, but in a very small proportion in alcohol. It does not deliquesce in the air; but when exposed to the rays of the sun, it becomes brown. Heat volatilizes the acid and revives the silver. ‡

21. Succinate.

Sp. 21. *Succinate of silver.* The succinic acid does not act on silver, but it dissolves its oxide, and forms with it a salt which crystallizes in thin oblong radiated prisms.§

Sp. 22. *Oxalate of silver.* Oxalic acid does not attack silver, but it dissolves a small portion of its oxide. The oxalate of silver, which was first examined by Bergman, may be formed by pouring oxalic acid into a solution of nitrate of silver. It is a white powder scarcely soluble in water, and not at all in alcohol; but soluble in nitric acid. It becomes black by being exposed to the air, owing to the reduction of the oxide. ||

23. Tartrate.

Sp. 23. *Tartrate of silver.* Tartaric acid does not attack silver; but tartar dissolves its oxide, and forms with it a saline mass, which becomes black by exposure to the air.** Tartaric acid does not occasion a precipitate in liquid nitrate of silver.

Sp. 24. *Tartrate of potash-and-silver.* Thenard has shown, that when tartar is poured into liquid nitrate of silver, a triple salt is formed, composed of tartaric acid, potash, and oxide of

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* Scheele, i. 146.

† Opusc. i. 106. This has been denied by Monnet, but found accurate by Kirwan. The saturated solution, filtered while hot, yielded him very speedily acicular crystals. He supposes that Monnet failed by evaporating the solution.—Kirwan on Mineral Waters, p. 81.

‡ Trommsdorf, Ann. de Chim. xi. 313.

§ Wenzel's Verwand. p. 245.

|| Bergman, i. 386.

** Wenzel's Verwand. p. 218,

silver. This salt is decomposed by the alkalies and their carbonates, and by the sulphates and muriates.*

Sp. 25. *Mellate of silver.* Mellitic acid occasions no precipitate in nitrate of silver.†

26. Citrate.

Sp. 26. *Citrate of silver.* Silver is not attacked by the citric acid; but its oxide combines with it, and forms with it a salt insoluble in water, of a harsh metallic taste, which blackens when exposed to the light, and yields, when distilled, acetic acid, while the silver is revived. This salt is decomposed by nitric acid. According to Vauquelin, to whom we are indebted for these facts, it is composed of

36	acid
64	oxide of silver
100 ‡	

Supposing it a compound of 1 atom acid + 1 atom oxide, its constituents must be

Citric acid	33·3
Oxide of silver	66·6
	100·0

For an atom of citric acid is just half the weight of an atom of oxide of silver.

Sp. 27. *Saclactate of silver.* Saclatic acid occasions a white precipitate when dropped into nitrate of silver.§

Sp. 28. *Malate of silver.* Scheele ascertained, that malic acid occasions a precipitate in nitrate of silver. But the nature of that precipitate has not been examined.||

29. Lactate.

Sp. 29. *Lactate of silver.* This salt is obtained by dissolving carbonate of silver in lactic acid. The solution has a greenish-yellow colour, and an unpleasant taste of verdigris. When evaporated in a very flat dish, it dries into a greenish-yellow varnish, with surface splendent like that of a mirror. When evaporated in a deep dish, it becomes brown from the reduction of part of the silver. Even in the yellow polished matter a portion of the silver is reduced, as becomes evident by dissolving the salt in water.** According to Braconnot lactic

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* Ann. de Chim. xxviii. 36.

† Klaproth's Beitrage, iii. 131.

‡ Fourcroy, vii. 209.

§ Scheele, ii. 80.

|| Crell's Annals, ii. 11. Eng. Trans.

** Berzelius, Djurkemien, ii. 438.

acid, from vegetables, readily dissolves oxide of silver when assisted by the application of heat. By evaporation, silky, needle-form crystals are formed, collected together in spheres, so that the whole liquid appears coagulated. When dried, it has a fine white colour, but becomes red by exposure to the light. It is soluble at the temperature of 73° in 20 times its weight of water. When heated, it melts, swells, becomes brown, catches fire, and leaves metallic silver.*

Such are the properties of the salts of silver, as far as they have been examined. They resemble the salts of mercury in being chiefly insoluble in water. The only one of them in common use is the nitrate, which is applied to a variety of purposes, both in chemistry and domestic economy. The composition of the salts of silver is easily ascertained by considering them as compounds of 1 atom oxide of silver, and 1 atom of each of the acids. The weight of an atom of oxide of silver is 14·75; that of the acids has been given in a preceding chapter of this volume.

SECT. XXXII.

SALTS OF GOLD.

Though gold was tortured with the most persevering industry by the alchymists and metallurgists, and has been an interesting object of examination to chemists in every period of the science, there is no genus of salts with which we are at present so little acquainted as those which have for their bases the oxides of that metal. This is not owing to the expense necessarily attending such investigations, but to the peculiar properties of gold itself. As that metal is not acted on by any of the acids, except the nitro-muriatic and chlorine, none of the salts of gold can be formed directly except the muriate; all the rest must be composed by precipitating the oxide of gold from its solution in nitro-muriatic acid, and afterwards dissolving it in the other acids. But this method, which is difficult, was not thought of till the nature of the oxides of gold was known; and since that point was ascertained, no chemist has considered these salts as worth investigating. It

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* Braconnot, Ann. de Chim. lxxxvi. 92.

is true, indeed, that they do not hold out those brilliant discoveries which attract adventurers to other parts of the science: yet it must be admitted that an accurate examination of the metallic salts requires as much address, ingenuity, and sagacity, and would contribute as much to the advancement of the science, as any other investigation whatever. It would throw a new light on mineralogy, and even on geology; it would enable us to develop with more precision the nature of affinity than has hitherto been done; and it would serve also as a touch-stone to try the truth of several chemical theories which are at present in vogue.

There are two oxides of gold known, the purple and the yellow; but as far as is known at present, the first of these does not combine with acids at all. Consequently, all the salts of gold are, strictly speaking, *persalts;* that is, composed of gold combined with a maximum of oxygen. We are only acquainted at present with two species of these salts, namely, the *muriate* and the *nitrate*.

The salts of gold may be ascertained by the following properties:

Characters.

1. They are soluble in water, and the solution has a yellow colour.

2. Ferrochyazate of potash occasions a white or yellowish-white precipitate when poured into these solutions.

3. Gallic acid or the infusion of nutgalls gives these solutions a green colour, and a brown powder is precipitated, which is gold reduced.

4. A plate of tin or muriate of tin occasions the precipitation of a purple-coloured powder.

5. Sulphate of iron precipitates the gold in the metallic state. Sulphurous acid produces the same effect.

The best way of examining the salts of gold would be to dissolve the metal in nitro-muriatic acid, to throw down the peroxide by means of carbonate of potash and heat, to wash this oxide sufficiently, and to dissolve it while still moist in the different acids. By this method, the salts of gold could be formed, and their properties ascertained.

1. Nitrate.

Sp. 1. *Nitrate of gold.* Nitric acid attacks the oxide of gold only when concentrated. The solution has a brown colour, and always contains a great excess of acid. When diluted with water, the oxide of gold precipitates. There appears to be but little affinity between nitric acid and oxide of gold. Hence no doubt the reason why this acid does not dissolve gold in the metallic state.* When the solution is heated, the gold is precipitated in the metallic state.

2. Sulphate. Sp. 2. *Sulphate of gold.* This salt is obtained by dissolving oxide of gold in warm sulphuric acid diluted with water. It has a yellow colour, a very styptic taste, and always contains an excess of acid. I do not know whether it be capable of crystallizing.

I am not acquainted with the properties of any of the other salts of gold.

SECT. XXXIII.

SALTS OF PLATINUM.

As platinum agrees with gold in its power of resisting all the acids except the nitro-muriatic and chlorine, the same obstacles lie in the way of an examination of the salts of platinum which have prevented us from getting acquainted with the last genus. We need not be surprised, therefore, that this genus is scarcely farther advanced than the last.

The salts of platinum may be distinguished by the following properties:

Characters. 1. Their solution in water has a brown or yellowish-brown colour.

2. Ferrochyazate of potash occasions no precipitate in these solutions.

3. Neither is any precipitate produced by gallic acid or the infusion of nutgalls.

4. Potash and ammonia occasion the precipitation of small orange-coloured crystals.

5. Sulphuretted hydrogen precipitates the platinum in the state of a black powder.

From the experiments of Mr. Edmund Davy there is reason to believe that no confidence can be placed in the experiments of Bergman and Chenevix on the salts of platinum. The only salts of this metal, therefore, with which we are at present acquainted, are the sulphate and the triple salts, consisting of the sulphate combined with alkaline and earthy salts.

1. Sulphate. Sp. 1. *Sulphate of platinum.* This salt was first noticed by Proust, in 1802,† and it was particularly examined by Mr. Edmund Davy, in 1812.‡ It may be obtained by passing a

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* Vauquelin, Ann. de Chim. lxxvii. 332.

† Ann. de Chim. xlix. 180.

‡ Philosophical Magazine, xl. 350.

current of sulphuretted hydrogen gas through the solution of platinum in nitro-muriatic acid. A black precipitate falls, which is to be washed and boiled to dryness in nitric acid. It is best to repeat the boiling a second time in order to ensure the complete conversion of the powder into sulphate of platinum.

Sulphate of platinum, thus formed, has a very dark-brown colour, approaching black. It is obtained in the form of a porous crust, similar to the carbonaceous matter left when sugar is decomposed by heat. It is very brittle and easily reduced to powder. Its lustre is somewhat similar to that of crystallized blende. Its taste is acid and metallic, with some degree of causticity. It slightly reddens litmus paper. It is very deliquescent, and of course very soluble in water. It is soluble in alcohol, ether, muriatic acid, nitric acid, and phosphoric acid. The alkalies form triple compounds with it. Its solution in water has a dark-brown colour of great intensity. Sal ammoniac does not occasion a precipitate when dropped into it; but, if the solution be boiled to dryness, the ammonio-muriate is formed. The sulphuric acid cannot be separated from this salt by any of the usual methods, in consequence of the disposition which the salt has of entering into triple compounds. When heated to redness, it is entirely decomposed, and metallic platinum obtained. Oxygen gas, and some sulphurous acid gas is obtained, and a liquid similar to the smoking sulphuric acid of the Germans. From the analysis of Mr. E. Davy, it appears that this sulphate is composed of

Sulphuric acid	26·3
Protoxide of platinum	73·7
	100·0

Now if we consider it as a compound of 1 atom sulphuric acid + 1 atom protoxide of platinum, its composition would be

Sulphuric acid	27·58
Protoxide of platinum	72·42
	100·00

Numbers which approach very near the experimental result of Mr. E. Davy.

Sp. 2. *Sulphate of potash-and-platinum.* When an aqueous solution of sulphate of platinum is neutralized by potash, and boiled for a few minutes, a dark-brown substance falls and the liquid remains colourless. This precipitate constitutes the salt in question.

It is a dark-brown or black substance, in grains not unlike those of gunpowder. It has a considerable lustre like that of blende. Its feel is harsh. It is tasteless, insoluble in water, not altered by exposure to the air, and not affected by boiling nitric acid. It is readily soluble in boiling muriatic acid; but nitro-muriatic acid has but little action on it. It is insoluble in boiling sulphuric, phosphoric, and acetic acids. Ammonia does not act on it. When boiled in solution of potash no apparent effect is produced; but if the solution be boiled to dryness, and heated, two distinct compounds appear to be formed. The one yellow, and the other olive. It is insoluble in alcohol and ether. In a red heat it is decomposed; oxygen, platinum, and sulphate of potash being produced. The constituents of this substance, according to the analysis of Mr. E. Davy, are as follows:

Protoxide of platinum	78·32
Sulphate of potash	10·84
Water	10·84
	100·00

This must be admitted to be a very extraordinary compound, and seems hardly entitled to the name of a salt. Its constituents must be

6 atoms of protoxide	77·97
1 atom sulphate of potash	10·89
10 atoms water	11·14
	100·00

Sp. 3. *Soda-sulphate of platinum.* This substance may be obtained by the same process as the preceding species, by merely substituting soda for potash. Its properties are quite similar, and, therefore, do not require a particular description. Its constituents, according to the analysis of Mr. E. Davy, are as follows:

Protoxide of platinum	84·16
Sulphate of soda	7·11
Water	8·73
	100·00

Hence it must be a compound of

8 atoms protoxide	83·83
1 atom sulphate of soda	7·18
10 atoms water	8·99
	100·00

Sp. 4. *Ammonio-sulphate of platinum.* This species is formed like the two preceding, by neutralizing an aqueous solution of sulphate of platinum with ammonia, and boiling for a few minutes. The substance in question precipitates, and may be washed and dried.

It has a light-brown colour, and is in powder or loosely aggregated lumps. It is tasteless, insoluble in water, and not altered by exposure to the air. It dissolves in muriatic acid, and in sulphuric acid when assisted by heat. When nitric acid is boiled upon it, the substance is decomposed, and a black matter remains. It is insoluble in acetic acid, and very slightly soluble in phosphoric acid. It is decomposed by being boiled in a solution of the fixed alkalies. When heated, it is decomposed with a kind of imperfect detonation. Mr. E. Davy did not analyze it with precision, but infers, from an experiment, that its constituents are

Oxide of platinum	70
Sulphate of ammonia and water	30
	100

Sp. 5. *Sulphate of barytes-and-platinum.* When a solution of muriate of barytes is poured into aqueous sulphate of platinum, a brown precipitate falls, which is the substance in question. It is tasteless, insoluble in water, and in boiling muriatic and nitric acids. Warm nitro-muriatic acid dissolves it, and so does sulphuric acid at a boiling temperature. It is not decomposed by the alkalies. When heated to redness, it gives out only water; no gas whatever is evolved. Mr. E. Davy, to whom we are indebted for these facts, did not analyze this compound.

Sp. 6. *Sulphate of alumina-and-platinum.* When muriate of alumina is poured into sulphate of platinum a gelatinous brown precipitate falls, which is the salt in question. It is a black shining powder, insoluble in water, and not altered by exposure to the air. It is insoluble in the cold mineral acids, and only slightly acted on by these acids at a boiling temperature. When heated to redness, it gives out merely water, and becomes lighter coloured. It contains at least 27 per cent. of water; but Mr. E. Davy, to whom we are indebted for the preceding facts, did not analyze it.

None of the other salts of platinum have been hitherto examined.

SECT. XXXIV.

SALTS OF PALLADIUM.

PALLADIUM has been so recently discovered, and is so scarce and difficult to procure in a state of purity, that an exact knowledge of the salts which it forms cannot be expected. To Dr. Wollaston and Mr. Chenevix we are indebted for all the facts respecting them hitherto published. They may be distinguished by the following properties:

Characters.

1. They are almost all insoluble in water, and the colour of the solution is a fine red.

2. Ferrochyazate of potash occasions an olive, or rather a dirty yellowish-brown precipitate.

8. Hydrosulphuret of potash occasions a blackish-brown precipitate.

4. The alkalies occasion an orange-coloured precipitate.

5. Mercury and sulphate of iron throw down the palladium in the metallic state.

6. Muriate of tin renders the solution opaque by throwing down a brown precipitate; but if the solution be sufficiently diluted, it assumes a fine emerald green colour.

Neither nitrate of potash nor sal ammoniac occasions any precipitate.

1. Nitrate.

Sp. 1. *Nitrate of palladium.* When palladium is put into a strong colourless nitric acid, the liquid gradually acquires a red colour; but the action of the acid is extremely slow, no nitrous gas whatever being extricated. This fact, hitherto unique in the history of the action of metals on nitric acid, explains in some measure the slowness of the action of the acid; and that circulation of the fluid which takes place during the solution of other metals is wanting. When the acid contains nitrous gas the action is more rapid.* The nitrate of

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* Wollaston on the Discovery of Palladium, Phil. Trans. 1805.

palladium, thus formed, is of a dark-red colour; by evaporation it yields a red matter, which is probably in the state of subnitrate.

2. Muriate.

Sp. 2. *Muriate of palladium.* Muriatic acid acts slowly upon palladium when assisted by heat, and assumes a fine red colour; but the true solvent of this metal is nitro-muriatic acid, which attacks it with great violence, and forms a beautiful red solution.* The properties of the salt thus formed have not been examined.

3. Sulphate.

Sp. 3. *Sulphate of palladium.* Sulphuric acid boiled upon palladium acquires a beautiful red colour, and dissolves a portion of the substance; but the action of this acid is not very powerful.† The properties of the salt thus formed have not been examined.

Sp. 4. *Muriate of palladium-and-soda.* When a solution of common salt or of soda is poured into muriate of palladium, no precipitate is separated, and by evaporation a triple salt is obtained, which is soda-muriate of palladium. This salt deliquesces when exposed to the air, a property which sufficiently distinguishes it from soda-muriate of platinum; for this last salt forms permanent crystals.‡

Sp. 5. *Muriate of palladium-and-potash.* When nitrate of potash is dissolved in muriatic acid, a liquid is formed, which acts readily upon palladium, but not upon platinum; because the muriate of platinum-and-potash is scarcely soluble in water, whereas the muriate of palladium-and-potash is remarkable for its solubility. The proportion which Dr. Wollaston, to whom we are indebted for the discovery, found to answer best, was 5 parts of acid diluted with its bulk of water and 1 part of nitre. The solution of palladium thus formed, which is of a deep-red, by evaporation yields crystals of muriate of palladium-and-potash. They are very soluble in water, but insoluble in alcohol. They are in the form of four-sided prisms, and present a curious contrast of colour. When viewed transversely they are of a bright green: but when viewed in the direction of their axes, their colour is the same as that of the solution: on account of its extreme intensity, however, this colour is with difficulty distinguished in fragments that exceed $\frac{1}{100}$th of an inch in thickness. When the

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* Chenevix on Palladium, Phil. Trans. 1803. † Chenevix, ibid.

‡ Wollaston on a New Metal found in Crude Platina. Phil. Trans. 1804

crystal is viewed obliquely it is of a dull-brown, arising from a mixture of the red and green.*

Sp. 6. *Muriate of palladium-and-ammonia.* This triple salt, like the last species, is very soluble in water, which distinguishes it sufficiently from the muriate of platinum-and-ammonia. Hence palladium is not thrown down from its solutions by sal ammoniac. This salt, according to Dr. Wollaston, resembles the last species in every respect.

7. Ferrochyazate.

Sp. 7. *Ferrochyazate of palladium.* When prussiate of mercury is poured into any neutral solution containing palladium, a flocculent precipitate of a pale yellow colour is gradually thrown down. This precipitate is prussiate of palladium. It is insoluble in water, and differs somewhat in its properties in different circumstances. In general, it is affected by heat, like other prussiates; but when the palladium has been dissolved in nitric acid, and precipitated from such a neutral solution by prussiate of mercury, the precipitate thus formed has the property of detonating when heated. The noise is similar to that occasioned by firing an equal quantity of gunpowder, and accordingly the explosion is attended with no marks of violence unless occasioned by close confinement. The heat requisite for the purpose is barely sufficient to melt bismuth. The light produced is feeble, and can be seen only in the absence of all other light.†

SECT. XXXV.

SALTS OF RHODIUM.

The properties of the salts belonging to this genus are too imperfectly known to admit of a detailed description. Dr. Wollaston examined them, only so far as to show that their base is the oxide of a peculiar metal. A few additional facts have been stated by Berzelius. They may be distinguished by the following properties:

Characters.

1. The solution of them in water is red.
2. Ferrochyazate of potash occasions no precipitate.
3. Neither is any precipitate produced by hydrosulphuret of potash.

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* Wollaston on a New Metal from Crude Platina.

† Wollaston on the Discovery of Palladium.

4. Neither sal ammoniac nor the alkaline carbonates occasion any precipitate; but the pure alkalies throw down a yellow powder soluble in an excess of alkali.

1. Nitrate.

Sp. 1. *Nitrate of rhodium.* The oxide of rhodium dissolved in nitric acid forms a red solution which does not crystallize.

Sp. 2. *Muriate of rhodium.* The oxide of rhodium forms a rose-coloured solution in muriatic acid. It does not crystallize; but the residuum is soluble in alcohol. Sal ammoniac, nitre, and common salt, cause no precipitation, but form triple salts, which are insoluble in alcohol.

3. *Soda-muriate of rhodium.* This triple salt, which has the taste of sulphate of soda, forms rhomboidal crystals, of which the acute angle is about 75°. They have a very dark-red colour, are not altered by exposure to the air. They dissolve readily in 1½ part of water, but not in alcohol.

4. Sulphate.

Sp. 4. *Sulphate of rhodium.* When hydrosulphuret of ammonia is mixed with soda-muriate of rhodium and heat applied a sulphuret of rhodium precipitates. When this sulphuret is treated with fuming nitric acid, it is converted into persulphate of rhodium, part of which dissolves in the acid, and another portion remains in the state of a black powder. When the whole nitric acid is driven off, the persulphate of rhodium remains behind. It deliquesces in the air and assumes a red colour. When dissolved in water and evaporated to dryness, it does not become black as at first, but a syrupy matter of an orange-colour which swells up in a greater heat and becomes spongy like calcined alum. In that state it dissolves slowly in water, and after two or three days is entirely dissolved in that liquid if left in contact with it. Caustic potash precipitates from it a pale yellow substance, which appears to be a triple subsulphate.

When exposed to a cherry-red heat sulphuric acid and oxygen gas are disengaged, leaving behind a black insoluble powder. This powder, according to Berzelius, is a protosulphate of rhodium.[*]

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[*] Berzelius, Annals of Philosophy, iii. 256.

SECT. XXXVI.

SALTS OF IRIDIUM.

Book II. Division II.

THIS genus of salts is still less known than the former. We are indebted to the French chemists, and to Mr. Tennant, for all the facts hitherto detailed.

Characters.

1. The salts of iridium appear to be soluble in water, and to have a colour at first green, but which changes to red by concentrating the solution in an open vessel.

2. Neither ferrochyazate of potash nor the infusion of nutgalls occasions any precipitate; but both render the solution colourless.

3. They appear to be partially precipitated by sal ammoniac; since Descotils has shown that the red colour which the muriate of platinum-and-ammonia sometimes assumes, is to be ascribed to the presence of iridium.

The only salt of iridium hitherto examined is the muriate. The solution of iridium in muriatic acid by slow evaporation yielded an imperfectly crystallized mass, which being dried on blotting paper and re-dissolved, formed by evaporation octahedral crystals of a red colour. These crystals dissolved in water, and formed a deep red solution inclining to orange.

SECT. XXXVII.

SALTS OF TELLURIUM.

THE oxide of tellurium stands as it were intermediate between the acids and the salifiable bases. It is capable, like acids, of combining with salifiable bases, and forming with them neutral salts. It is capable likewise of combining with acids as the salifiable bases do, and of forming with them neutral salts. We have therefore two genera of salts of tellurium. 1. Salts in which the oxide of tellurium acts the part of an acid. 2. Salts in which the oxide of tellurium acts the part of a base. I shall describe these two genera separately, after giving the characters by which the salts of tellurium may be recognised.

Characters.

The salts of tellurium may be distinguished by the following properties:

1. Alkalies, when dropped into their solution, occasion a white precipitate, which disappears again if the alkali be added in excess.

2. Ferrochyazate of potash occasions no precipitate.

3. Hydrosulphuret of potash occasions a brown or blackish precipitate.

4. The infusion of nut-galls occasions a flaky precipitate of a yellow colour.

5. Zinc, iron, and antimony, when plunged into these solutions, occasion the tellurium to separate in the state of a black powder, which resumes its metallic brilliancy when rubbed.*

GENUS I. SALTS IN WHICH THE OXIDE OF TELLURIUM ACTS THE PART OF AN ACID.

These salts have been hitherto examined only by Berzelius, and his examination was but imperfect, owing to the small quantity of tellurium in his possession. The following are the facts which he ascertained:

1. *Tellurate of ammonia.* When oxide of tellurium is digested in ammonia it dissolves. As the solution cools it deposites a white powder, which is tellurate of ammonia.†

2. *Tellurate of potash.* If oxide of tellurium be mixed with nitre, and the mixture be exposed to heat, the nitre at first melts without acting on the oxide. But at the temperature in which the oxide begins to liquify, it decomposes the saltpetre with a violent effervescence, the nitric acid is driven off, and the oxide dissolves in the potash. The mass when cold very much resembles an enamel. It dissolves in boiling water and the solution on cooling deposites an imperfectly crystallized white powder. This is tellurate of potash. It dissolves in small quantity in cold water and in much greater proportion in boiling water. The hot solution deposites the salt in powder on cooling. It has a slight metallic taste and acts feebly as an alkali on vegetable blues.‡

3 and 4. *Tellurate of lime and barytes.* White powders formed by dropping tellurate of potash into muriate of lime or of barytes.§

5. *Tellurate of copper.* Tellurate of potash occasions a beautiful emerald-green precipitate when dropped into sulphate of

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* Klaproth's Beitrage, iii. 1; and Crell's Annals, 1798, i. 98.

† Berzelius, Nicholson's Journal, xxxvi. 131.

‡ Ibid. 130.

§ Ibid. 131.

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copper. This precipitate is tellurate of copper. When heated it gives out water and becomes black. When more strongly heated it melts into a black glass. When heated on red-hot charcoal it is reduced with detonation like nitre and leaves an alloy of tellurium and copper of a pale red colour.*

6. *Remaining tellurates.* Tellurate of potash precipitates persulphate of iron *red*, and solutions of zinc, mercury, lead, silver, and manganese *white*.†

Tellurate of lead is a whitish powder. When heated it loses its water of combination, and becomes yellow. In a little higher temperature it fuses and forms a semitransparent mass similar to chloride of lead. This tellurate according to the experiments of Berzelius is composed of

Oxide of tellurium	42·2
Protoxide of lead	57·8
	100·0‡

If we suppose it a compound of 2 atoms oxide of tellurium and 1 atom of protoxide of lead, its composition will be

Oxide of tellurium	41·66
Protoxide of lead	58·33
	100·00

The salt of course is a bitellurate.

GENUS II.—SALTS WITH BASE OF TELLURIUM.

Berzelius found that oxide of tellurium combines with sulphuric, muriatic, and nitric acids, and forms with them neutral salts.§ The following are the facts which have been ascertained respecting the action of these acids on tellurium.

1. *Nitrate of tellurium.* Nitric acid dissolves tellurium with facility. The solution is colourless, and not rendered turbid by water. It yields, when concentrated, small, white, light, needle-form dendritical crystals.‖

2. *Muriate of tellurium.* Nitromuriatic acid dissolves tellurium readily. The solution is transparent; but when diluted with water, it lets fall the oxide of tellurium in the state of a white precipitate, which is re-dissolved on adding more water.

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* Berzelius, Nicholson's Journal, xxxvi. 131.

† Ibid. ‡ Ibid. 132. § Ibid. 130.

‖ Crell's Annals, 1798, i. 98.

When the solution is precipitated by alcohol, and sufficiently washed, the white powder contains but a very small proportion of acid.*

3. *Sulphate of tellurium.* When one part of tellurium is confined with 100 parts of sulphuric acid in a close vessel, it dissolves and gives the acid a crimson colour. When water is dropped into the acid, the red colour disappears, and the metal is precipitated in black flakes. When heated, the colour equally disappears, and the metal precipitates in the state of a white powder. Diluted sulphuric acid, mixed with a little nitric acid, dissolves a considerable portion of tellurium, the solution is colourless, and no precipitate is produced in it by water.†

SECT. XXXVIII.

SALTS OF ANTIMONY.

The protoxide of antimony is capable of uniting with acids and forming salts; while its deutoxide and peroxide possess acid properties. Hence the salts of antimony might be divided into three genera, corresponding to the three oxides which the metal forms. But I thought it better to describe the *antimoniates* and *antimonites* while treating of the different bases with which antimonious and antimonic acid combine. Here therefore I have only to describe the few known salts that contain protoxide of antimony.

Antimonial salts may be distinguished by the following properties:

Characters.

1. Their solutions are usually of a brownish yellow colour, and in most cases a white precipitate falls when they are diluted with water.

2. Ferrochyazate of potash occasions a white precipitate when dropped into these solutions. This precipitate is merely the oxide of the metal precipitated by the water of the ferrochyazate. When applied sufficiently concentrated, or in crystals, no precipitation takes place. In this property antimony agrees with platinum.‡

3. Hydrosulphuret of potash occasions an orange-coloured precipitate.

4. Gallic acid and the infusion of nut-galls occasion a white

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* Klaproth's Beitrage, iii. 13.

† Crell's Annals, 1798, i. 98.

‡ Klaproth, Crell's Annals, 1798, i. 99.

precipitate, which is merely the oxide of the metal separated by the water of the infusion.

5. When a plate of iron or zinc is plunged into antimonial solutions, a black powder precipitates in great abundance, and very speedily when there is an excess of acid, and the solution is not too much concentrated.

Neither nitric, sulphuric, phosphoric, or carbonic acid form salts with protoxide of antimony, at least we are not acquainted at present with any such combinations. The most important, and indeed the only well-known antimonial salt, is the following:

Tartar emetic.

Sp. 1. *Tartrate of potash-and-antimony.* This salt, usually denominated *tartar emetic*, is much more employed in this country as a medicine than all the other antimonial preparations put together. It was first made known by Adrian de Mynsicht in his *Thesaurus Medico-Chymicus*, published in 1631. But the preparation was in all probability suggested by a treatise, entitled *Methodus in Pulverem*, published in Italy in 1620. This book, written by Dr. Cornachinus, gives an account of the method of preparing a powder which had been invented by Dudley Earl of Warwick, and which had acquired great celebrity in Italy in consequence of the wonderful cures which it had performed. This powder was composed of scammony, sulphuret of antimony, and tartar, triturated together. The extraordinary effects which it produced would naturally draw the attention of chemists to the combination of antimonial preparations with tartar.

History.

Preparation.

Tartar emetic was first prepared by boiling together tartar and the *crocus metallorum*,* as it was called, in water, filtering the solution, and evaporating it till it yields crystals: glass of antimony was afterwards substituted for the crocus. But it would be needless to enumerate the various methods which have been adopted according to the fancy of different operators. These methods have been collected by Bergman, and are described by him in his treatise on *Antimoniated Tartar*.† The processes followed in London may be seen in Mr. Philips' *Experimental Examination of the Pharmacopœa Londinensis, p.* 58.

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* An impure hydrosulphuret, formed by detonating in a crucible equal weights of sulphuret of antimony and nitre, and washing the residuum in water till the liquid comes off tasteless.

† Opusc. i. 338.

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At present, the glass of antimony, or the protoxide of antimony, are usually employed. Either of these is mixed with its own weight of tartar, and the mixture boiled in ten or twelve parts of water, till the tartar be saturated. The solution is then filtered and evaporated till a pellicle forms on its surface. On cooling it deposites regular crystals of tartar emetic. Thenard has observed, that there always remains in the solution a quantity of uncombined tartrate of potash; it ought not therefore to be evaporated too far, otherwise the crystals of that salt will mix with those of the tartar emetic.[*]

Properties.

Tartar emetic is of a white colour, and crystallizes in regular tetrahedrons. When exposed to the air, it gradually loses its transparency and effloresces. It is soluble in 14¼ parts of cold water, and in about two parts of boiling water.[†] Heat decomposes it by destroying the acid, while the potash and oxide of antimony remain behind. It is decomposed by the alkaline earths, by the alkalies and their carbonates, and by the hydrosulphurets, and several of the metals. It is decomposed also by the decoctions of plants, particularly those that are astringent and bitter, as Peruvian bark, &c. Consequently it never ought to be given in conjunction with any of these bodies.

Mr. Philips informs us that 100 parts of tartar are capable of dissolving 66 parts of protoxide of antimony. From this statement, compared with my analysis of tartar, it follows that tartar emetic is a compound of

Tartaric acid	44·21
Protoxide of antimony ..	39·76
Potash	16·03
	100·00

Now if we suppose the salt a compound of 2 atoms tartaric acid, 2 atoms protoxide of antimony, and 1 atom of potash, its composition will be

Tartaric acid	46·53
Protoxide of antimony ..	36·81
Potash	16·66
	100·00

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[*] Ann. de Chim. xxxviii. 39.

[†] Buckhal, Ann. de Chim. xlix. 70.

The salt therefore seems to be a compound of 1 atom of tartrate of potash, and 1 atom of subtartrate of antimony.

I conceive it to be worth while to state the following facts respecting the action of the vegetable acids on antimony, though some of them would require to be re-examined.

Other salts.

Sp. 2. *Acetate of antimony.* Acetic acid has little or no action on antimony; but it dissolves a small portion of its oxide, as Morveau has shown, and the solution, according to Wenzel, yields small crystals.* This salt is soluble in water, and was employed by Angelus Sala and some subsequent physicians as an emetic.†

Sp. 3. *Succinate of antimony.* Succinic acid does not attack antimony, but it dissolves a portion of its protoxide, and forms a salt which has not been examined.

Sp. 4. *Benzoate of antimony.* Benzoic acid readily dissolves the oxide of antimony, and the solution yields crystals, which remain dry when exposed to the air, and are decomposed by heat.‡

Sp. 5. *Oxalate of antimony.* Oxalic acid scarcely attacks antimony; but it dissolves a small portion of its oxide. The solution yields by evaporation small crystalline grains difficultly soluble in water. The same salt is precipitated by adding oxalic acid to the solution of antimony in acetic or sulphuric acid; but oxalic acid occasions no precipitate in butter of antimony.§

Sp. 6. *Tartrate of antimony.* Tartaric acid has no action on antimony, but it dissolves a small portion of its oxides. The solution scarcely crystallizes; but easily assumes the form of a jelly.‖

SECT. XXXIX.

SALTS OF TITANIUM.

For all that is at present known respecting this genus of salts we are indebted to the experiments of Gregor, Klaproth, Vauquelin, and Hecht. The salts of titanium may be distinguished by the following properties:

Characters.

1. They are in general colourless, and in some degree soluble in water.

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* Verwandtschaft, p. 158.

† Encyc. Method. Chim. i. 6.

‡ Trommsdorf, Ann. de Chim. xi. 317.

§ Bergman, i. 271.

‖ Ibid.

2. The alkaline carbonates occasion in these solutions a white flaky precipitate.

3. Ferrochyazate of potash occasions a grass-green precipitate mixed with brown. When an alkali is dropped in after the ferrocyhazate, the precipitate becomes purple, then blue, and at last white.

4. Hydrosulphuret of potash occasions a dirty glass-green precipitate. Sulphuretted hydrogen gas occasions no precipitate.

5. The infusion of nut-galls occasions a very bulky reddish-brown precipitate. If the solution is concentrated, it assumes the appearance of curdled blood.

6. When a rod of tin is plunged into a solution of titanium, the liquid around it gradually assumes a fine red colour. A rod of zinc, on the other hand, occasions a deep blue colour.*

Nitrate.

Sp. 1. Nitric acid has no action on the red oxide of titanium, and scarcely any upon the metal; but it dissolves the carbonate, provided heat be applied; and the solution yields, by evaporation, transparent crystals, in the form of elongated rhombs, having two opposite angles truncated, so as to represent six-sided tables. According to Vauquelin and Hecht, this solution only succeeds when the metal is combined with a minimum of oxygen.

Muriate.

Sp. 2. Muriatic acid dissolves titanium; but it has no effect upon its red oxide. The carbonate of titanium is readily dissolved by this acid; and the solution, according to Klaproth, yields transparent cubic crystals. According to Vauquelin and Hecht, the solution is yellow, and assumes the form of a jelly when evaporated. Heat occasions the emission of chlorine, and the oxide precipitates, and is no longer soluble in muriatic acid, unless it be boiled in nitric acid. Hence they conclude, that the muriate contains titanium combined with a maximum of oxygen, and that the protoxide is incapable of uniting with muriatic acid.

Sulphate.

Sp. 3. Boiling sulphuric acid oxidizes titanium, and dissolves a small portion of it; but on the red oxide of titanium that acid has no action whatever. It dissolves the carbonate of that metal with effervescence, occasioned by the emission of carbonic acid. The solution, when evaporated, is converted into a white opaque gelatinous mass.

Sp. 4 and 5. When the phosphoric or arsenic acid is drop-

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* Klaproth's Beitrage, i. 233.

ped into the solution of titanium in acids, it occasions a white precipitate.

Carbonate.

Sp. 6. When one part of red oxide of titanium and six parts of carbonate of potash are melted together in a crucible, the mass, when washed sufficiently with water, leaves a white powder, with a slight red tinge, which Vauquelin and Hecht have ascertained to be carbonate of titanium. According to the experiments of these chemists, it is composed of

75	white oxide
25	carbonic acid
100	

Sp. 7 and 8. Oxalic and tartaric acids likewise occasion a white precipitate, but it is redissolved again almost as soon as formed.*

CHAP. III.

OF THE COMBINATIONS OF SULPHURETTED HYDROGEN WITH BASES.

SULPHUR and hydrogen combine in two proportions at least, and form two compounds which have been distinguished by the names of *sulphuretted hydrogen* and *bisulphuretted hydrogen.*

Sulphuretted hydrogen possesses the characters of an acid, as was first shown by Mr. Kirwan, and afterwards more fully by Berthollet. The Germans in consequence have given it the name of *hydrothionic acid*,† and Gay-Lussac calls it *hydrosulphuric* acid.‡ But as these new terms, especially the last, are likely to lead to confusion, I shall still retain the old name, which is precise, and cannot mislead.

Water saturated with this gas becomes whitish and depo-

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* Jour. de Min. No. xv. p. 1.

† From *hydrogen*, and θειον, sulphur.

‡ This is the name by which Sir H. Davy distinguishes common sulphuric acid of the shops. But such a distinction is surely unnecessary, as every body is aware of the presence of water in that body. Were Sir Humphry's method to be followed out, we should say *hydroalcohol*, *hydrosulphate of soda*, *hydrosoap*, *hydrosugar;* in short we should lengthen out nine-tenths of all chemical names by prefixing to them the two syllables *hydro*.

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sits a little sulphur, but the gas is not decomposed. The addition of sulphurous acid immediately throws down abundance of sulphur. So does nitric acid and chlorine.

Sulphuretted hydrogen gas precipitates the metals which have but a weak affinity for oxygen from all their acid solutions in the state of sulphurets. But the metals which have a strong affinity for oxygen, and are capable of decomposing water, namely,

1. Iron,
2. Nickel,
3. Cobalt,
4. Manganese,
5. Uranium,
6. Cerium,
7. Titanium,

are not precipitated when held in solution by the strong mineral acids. But they are imperfectly precipitated, as Gay-Lussac has shown, when they are held in solution by acetic acid, or any other vegetable acid, and the precipitation becomes complete when acetate of potash is at the same time added to the solution.*

The metallic solutions differ considerably in the facility with which they afford precipitates with sulphuretted hydrogen; and Mr. Proust has shown that, with a little address, metals may, in many cases, be separated from each other by means of this agent. For instance, if copper, lead, zinc, and iron, be held in solution together in nitric acid, sulphuretted hydrogen first separates the copper in the form of a black precipitate, which may be removed by filtration; next the lead; and lastly, the zinc; while the iron still continues in solution.† The different metals may be distinguished by the colour of the precipitate which their solutions yield with sulphuretted hydrogen. The colours of these different precipitates may be seen in the following table:

Gold and Platinum	Reduced
Silver	Black
Mercury	Black
Palladium	Dark brown
Copper	Black
Tin	Brown
Lead	Black
Zinc	White
Bismuth	Black
Antimony	Orange

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* Ann. de Chim. lxxx. 205.

† Jour. de Phys. li. 174.

Arsenic	Yellow
Molybdenum	Chocolate

Bisulphuretted hydrogen was first observed by Scheele;[*] and Berthollet,[†] who first examined its nature, has given it the name of *hydroguretted sulphur.*

When liquid potash and sulphur are boiled together, a brown-coloured solution is obtained, formerly known by the name of *liquid hepar sulphuris.* If this liquid be poured by little and little into muriatic acid, scarcely any sulphuretted hydrogen gas is exhaled, but hydroguretted sulphur gradually precipitates to the bottom of the vessel, under the form of a yellowish brown oil. This substance, when heated, easily allows the sulphuretted hydrogen gas to exhale, and is converted into sulphur. The same change takes place when it is exposed to the open air.

The easiest method of procuring this substance, according to Proust, is to pour into a phial about $\frac{1}{3}$d of its capacity of muriatic acid, of the specific gravity 1·07, add about an equal bulk of the liquid hepar, cork the phial and shake it, the hydroguretted sulphur gradually separates.[‡]

Sulphuretted hydrogen is a compound of 1 atom hydrogen and 1 atom sulphur. Hydroguretted sulphur has not been analysed; but it is probably a compound of 1 atom hydrogen, and 2 atoms sulphur. The compounds formed by the union of sulphuretted hydrogen and bases, have been called *hydrosulphurets,*[§] those of hydroguretted sulphur and bases have been called *hydroguretted sulphurets.* I shall describe both of these compounds in this chapter, as far as our imperfect knowledge of the subject will permit.

SECT. I.

OF HYDROSULPHURETS.

Sulphuretted hydrogen combines with alkalies and earths, and forms with them compounds which may be distinguished by the following properties:

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[*] Scheele on Fire, p. 192. Eng. Trans.

[†] Ann. de Chim. xxv. 247.

[‡] Jour. de Phys. lix. 270. I have never myself been able to procure it by this process.

[§] Gay Lussac calls them *hydrosulphates.*

Properties.

1. They are all soluble in water, and the solution is colourless.

2. When the solution is exposed to the air, it becomes green or greenish yellow.

3. After long exposure to the air, the solution becomes limpid and colourless; and on examination is found to contain only the sulphite and hyposulphite of the base of the original hydrosulphuret.

4. The solution of the hydrosulphurets precipitates all metallic solutions: iron and lead, black; antimony, orange; arsenic, yellow.*

How formed.

The hydrosulphurets may be formed by dissolving or mixing the bases respectively with water, and causing sulphuretted hydrogen gas to pass through them till they refuse to absorb any more. The excess of the gas is driven off by heating the solution. It is proper to cause the sulphuretted hydrogen gas to pass through a small vessel of water before it reaches the base with which it is to combine, in order to separate any impurities with which it might be mixed. By this method solutions of the different hydrosulphurets in water may be obtained.

If these compounds be decomposed while they are colourless, by pouring upon them sulphuric acid, muriatic acid, or any other acid which does not act upon hydrogen, the sulphuretted hydrogen gas exhales without the deposition of a single particle of sulphur; but if the hydrosulphuret has become yellow, some sulphur is always deposited during its decomposition, and the quantity of sulphur is proportioned to the deepness of the colour.

The yellow colour, therefore, which hydrosulphurets acquire by exposure to the atmosphere, is owing to a commencement of decomposition. Part of the hydrogen of the sulphuretted hydrogen abandons the sulphur, combines with the oxygen of the atmosphere, and forms water. By degrees, however, a portion of the sulphur is also converted into an acid; and when the proportion of sulphuretted hydrogen is diminished, and that of the sulphur increased to a certain point, the sulphur and the hydrogen combine equally with oxygen.

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* When the hydrosulphurets are kept in glass phials, the inside of the vessel is gradually coated with a black crust. This, as I am informed by Dr. Henry, consists of a portion of the lead from the glass, reduced to the metallic state, and combined with sulphur.

If sulphuric or muriatic acids be poured upon a hydrosulphuret after it has been for some time exposed to the air, a quantity of sulphuretted hydrogen gas exhales, sulphur is deposited, and after an interval of time sulphurous acid is disengaged. It is, in fact, hyposulphurous acid, which is formed while the hydrosulphuret spontaneously absorbs oxygen.

1. Ammonia.

Sp. 1. *Hydrosulphuret of ammonia.* This compound is easily procured by passing a current of sulphuretted hydrogen through liquid ammonia. The solution very readily assumes a greenish-yellow colour. When equal parts of lime, sal ammoniac, and sulphur, are distilled in a retort, a yellow liquid is obtained, usually distinguished by the name of *fuming liquor of Boyle*, because first prepared by that philosopher. This liquid constantly emits white fumes, and has a strong ammoniacal and fetid odour. Berthollet ascertained that it owed its property of emitting fumes to a quantity of uncombined alkali. It consists chiefly of hydrosulphuret of ammonia holding an excess of sulphur. This liquid gradually loses the property of fuming, and deposits likewise its excess of sulphur. It is then a hydrosulphuret of ammonia nearly pure.

Pure hydrosulphuret of ammonia may be obtained by causing sulphuretted hydrogen gas and ammoniacal gas to pass into a bottle surrounded with ice. It crystallizes in needles, and is transparent and colourless. It is very volatile, and, when kept in a bottle, sublimes gradually to the top of the vessel, where it crystallizes in long transparent plates. By this spontaneous volatilization, it is easily freed from any impurities with which it may be mixed. When exposed to the air, it speedily becomes yellow.* If we suppose hydrosulphuret of ammonia, as is probable, composed of 1 atom sulphuretted hydrogen and 1 atom ammonia, its constituents will be

Sulphuretted hydrogen	2·125	50
Ammonia	2·125	50
		100

An integrant particle of it will weigh 4·25, and will contain 6 atoms; 4 of hydrogen, 1 of sulphur, and 1 of azote.

2. Of potash.

Sp. 2. *Hydrosulphuret of potash.* This compound may be procured by saturating potash with sulphuretted hydrogen; but it is formed also during the solution of sulphuret of pot-

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* Thenard, Ann. de Chim. lxxxiii. 154.

ash, and may be obtained by evaporation. Its properties have been described by M. Vauquelin. It is transparent and colourless, and crystallizes in large prismatic crystals, not unlike sulphate of soda. They are usually four-sided, and terminated by four-sided pyramids. Sometimes both the prisms and terminating pyramids are six-sided. Its taste is alkaline and extremely bitter. When exposed to the air, it soon deliquesces into a liquid of a syrupy consistence, tinging green all bodies with which it happens to be in contact. But this colour is not permanent, unless some metallic body happens to be in contact. The crystals have no smell; but when they have deliquesced they emit a fetid odour. They dissolve both in water and alcohol; and during the solution the temperature of the liquid sinks considerably. Acids drive off the sulphuretted hydrogen with a violent effervescence, and no sulphur is deposited. When thrown into sulphate of alumina, crystals of alum are soon deposited. This salt, like the other hydrosulphurets, precipitates all metals from their solutions.[*]

3. Of soda.

Sp. 3. *Hydrosulphuret of soda.* This compound may be prepared by the same processes as the last. It is the best known of all the hydrosulphurets, as it is usually employed as a reactive. The properties of its solution in water were first pointed out by Berthollet, but Vauquelin first obtained it crystallized. Having laid aside a concentrated solution of impure carbonate of soda[†] to crystallize, crystals of hydrosulphuret of soda formed in it spontaneously. The crystals of this hydrosulphuret are transparent and colourless, having the figure of four-sided prisms terminated by quadrangular pyramids, and sometimes of octahedrons. Its taste is alkaline and intensely bitter. It is very soluble both in water and alcohol; and during the solution cold is produced. When exposed to the air it deliquesces, and assumes a green colour. Acids decompose it, driving off the sulphuretted hydrogen. Its other properties are common to the hydrosulphurets.[‡]

Hydrosulphuretted sulphite of soda.

Though sulphuretted hydrogen and sulphurous acid mutually decompose each other when both are uncombined, this does not appear to be the case when they are united to a base. When water impregnated with sulphuretted hydrogen gas is mixed with liquid sulphite of soda, the smell of the gas is de-

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[*] Vauquelin, Ann. de Chim. xlii. 40.

[†] This carbonate had been procured by decomposing sulphate of soda by charcoal, and separating the sulphur by means of lime.

[‡] Vauquelin, Ann. de Chim. xli. 190.

stroyed, and by evaporation a salt is obtained which appears to be a triple compound of the two gaseous bodies with soda. A salt similar to this has been described by Vauquelin, who indeed formed it artificially by the process just detailed. This salt is white and transparent, crystallizes in four-sided prisms, has no smell, and is not altered by exposure to the air. Its taste is cooling, bitter, and slightly alkaline. When heated it melts, then becomes again solid, gives out sulphur, and the residue assumes a deep red colour. No gas is disengaged.*

Sp. 4. *Hydrosulphuret of lime.* This compound is easily prepared by passing sulphuretted hydrogen gas through lime suspended in water. The lime dissolves and the hydrosulphuret forms. The solution is colourless, and has an acrid and bitter taste. Its properties are analogous to the other hydrosulphurets. No attempts have been yet made to procure this compound in crystals.

5. Of barytes.

Sp. 5. *Hydrosulphuret of barytes.* When sulphate of barytes is converted into sulphuret, by mixing it with charcoal and keeping it red hot in a crucible, if boiling water be poured upon the black mass, and filtered while hot, the green-coloured solution thus obtained yields by evaporation a great number of crystals. These crystals are hydrosulphuret of barytes. They are to be separated immediately by filtration, and dried between the folds of filtering paper.† They are white, and have a silky lustre. They have usually the form of scales, whose shape cannot be easily ascertained. This compound is soluble in water, and the solution has a very slight tinge of green. Its taste is acrid and sulphurous; and when exposed to the air it is readily decomposed.

Sp. 6. *Hydrosulphuret of strontian.* I have procured this compound by the same process as the hydrosulphuret of barytes, and its properties are so nearly similar, that it requires no peculiar description.

7. Of magnesia.

Sp. 7. *Hydrosulphuret of magnesia.* Water, impregnated with sulphuretted hydrogen, dissolves magnesia, and forms a hydrosulphuret, the properties of which have not been examined.‡

Sp. 8 and 9. *Hydrosulphuret of glucina and yttria.* From

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* Vauquelin, Ann. de Chim. xxxii. 296. I have little doubt that this salt is a hyposulphite of soda; though I have not ventured to put it into the preceding chapter without having an opportunity of examining it.

† Berthollet, Ann. de Chim. xxv. 241.

‡ Ibid. 235.

the experiments of Vauquelin and Klaproth, we know that the hydrosulphurets do not precipitate those earths from acids. Hence it is likely that they are capable of combining with sulphuretted hydrogen; though the compounds have never been examined by chemists. Neither alumina nor zirconia combine with sulphuretted hydrogen. Hence the hydrosulphurets precipitate these earths from acids, in consequence of the affinity of their base for the acid, which holds the earths in solution; and at the same time sulphuretted hydrogen gas is emitted.

When these hydrosulphurets are exposed to the temperature of boiling water, a portion of the sulphuretted hydrogen is driven off. When they are boiled in contact with sulphur, a portion of the sulphur is dissolved, while sulphuretted hydrogen is given out.

Our knowledge of the remaining hydrosulphurets is too imperfect to enable us to continue their description. I shall place the few facts with which we are acquainted in a section by themselves.

SECT. II.

OF HYDROGURETTED SULPHURETS.

How formed.

The different alkaline and earthy bases are capable of combining with hydroguretted sulphur, and forming with it compounds which have been longer known than the hydrosulphurets, though their properties have not been examined with the same precision. They may be formed by boiling the base together with sulphur in a quantity of pure water, or by dissolving their sulphurets in water; in either case, hydroguretted hydrogen is formed, which combines with the base. These compounds were known formerly by the name of *liquid hepars*, or *livers of sulphur*. They may be formed also, as Berthollet has shown, by pouring a liquid hydrosulphuret upon sulphur. A portion of the sulphur is dissolved without the assistance of heat; the liquid becomes dark-coloured, and is converted into hydroguretted sulphuret.* When prepared by the first process, they contain an excess of sulphur, which separates when sulphuretted hydrogen is made to pass through them.

There can be little doubt that these compounds, if they

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* Ann. de Chim. xxv. 242.

could be obtained in a state of complete purity, would consist merely of hydroguretted sulphur united to the different bases. But, during their formation, both sulphurous and hyposulphurous acid seem to be formed, which the presence of the base prevents from being decomposed. Hence the hydroguretted sulphurets, as they are commonly obtained, contain both sulphites and hyposulphites, salts which modify the hydroguretted sulphurets so much, that it is difficult to recognise their true properties. The following are the facts hitherto observed.

Hydroguretted sulphuret of potash.

1. When the hydrate of potash and flowers of sulphur are mixed together in a phial, they act upon each other in a very short time, heat is evolved, and hydroguretted sulphuret formed of a fine red colour, which exhales sulphuretted hydrogen gas when treated with an acid. Liquid potash of the specific gravity 1·26, when kept for 10 or 12 hours upon flowers of sulphur, dissolves it and forms a similar compound. When heat is applied the combination takes place much sooner. When dry sulphuret of potash is dissolved in water, the same kind of compound is produced.* In all these cases the appearance of the hydroguretted sulphuret is the same, though its properties differ considerably. When it is formed by heat, the quantity of sulphuretted hydrogen which it yields by means of acids is always inconsiderable, and often not perceptible. By trial, I find that this depends in a great measure upon the care with which it has been kept from the contact of the air.

Liquid hydroguretted sulphuret of potash or soda, thus formed, is a liquid of a deep red colour verging upon brown; sometimes it has no smell; sometimes, as noticed by Proust, it has the smell of radishes; and by keeping it acquires the smell of sulphuretted hydrogen. Its taste is acrid, and as it were bitter and cooling. It stains the skin of a deep green. When kept in close vessels, it is said to deposit sulphur and to become colourless, being converted into a hydrosulphuret.† It attacks with great energy every metal, and often reduces it to the state of a sulphuret. Stahl demonstrated long ago, that it is capable of dissolving even gold. The nature of this

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* Proust, Jour. de Phys. lix. 266.

† With me this has never happened, though I have kept it in close vessels for years. It soon becomes colourless in vessels not closely shut, being converted into hyposulphite of potash.

solution has not been ascertained. By means of acids the gold is thrown down in the metallic state, and mixed with sulphur.

Ammonia.

2. When ammonia is kept in contact with the flowers of sulphur, it gradually dissolves a portion of it, and assumes a yellow colour, but does not acquire the odour of sulphuretted hydrogen.* Hydroguretted sulphuret of ammonia may be obtained by pouring on sulphur the hydrosulphuret of ammonia. The last portion of the liquid which passes over during the distillation of the *fuming liquor of Boyle* is also a hydroguretted sulphuret. This compound very readily deposits the excess of sulphur which it contains, and approaches to the state of a hydrosulphuret.

Barytes and strontian.

3. The hydroguretted sulphurets of barytes and strontian may be procured by dissolving their sulphurets in water, or even by exposing them to the open air. They have a green colour and acrid taste, but much inferior in intensity to the fixed alkaline hydroguretted sulphurets: neither is their action on other bodies so powerful.

Lime.

4. When a mixture of lime and sulphur is boiled in water, the liquid assumes a beautiful orange colour, and contains in solution hydroguretted sulphuret of lime. This liquid has likewise a very bitter taste. It is the only liquid at present known which is capable of dissolving a notable quantity of azotic gas. When kept in close phials, it gradually deposits sulphur, united to the oxide of the glass, in the state of black crust, and becomes perfectly colourless, being converted into hyposulphite of lime.

If three parts of slacked lime and one part of sulphur be boiled for an hour with twenty parts of water, and the liquid be decanted while yet hot from the undissolved portion into bottles exactly full and stopped, a few delicate bundles of orange-coloured crystals are deposited after some days standing. If the solution be allowed to cool and remain for some hours in contact with the sediment, a very copious formation of them takes place throughout its whole substance bristling over its surface, and even hanging down from that of the liquid. If they be washed with water, and dried in vacuo by means of sulphuric acid, they become permanent in a dry atmosphere. These crystals were first noticed and described by Mr. Herschel. They have the form of four-sided prisms, somewhat

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* Proust, Jour. de Phys. lix. 269.

elongated and terminated by dihedral summits. They are very sparingly soluble in water. Water saturated with them between the temperature of 32° and 45° has the specific gravity 1·0105. It has a wine-yellow colour, and an acrid, bitter, and sulphureous taste. Hot water dissolves a much larger proportion which it does not deposit on cooling unless lime or some other body in fine powder be added. According to the analysis of Mr. Herschel these crystals are composed of 1 atom of bisulphuretted hydrogen, united to 2 atoms of lime, and 4 atoms of water, or of

Bisulphuretted hydrogen	4·125	25·99
Lime	7·250	45·67
Water	4·500	28·34
	15·875	100·00*

This is the only crystallized hydroguretted sulphuret that we are yet acquainted with.

Magnesia. 5. The hydroguretted sulphuret of magnesia may be formed by the same processes as the others. This compound has scarcely been examined. It has but little permanency.

6. It has not been proved that the earths proper are capable of combining with bisulphuretted hydrogen, and forming hydroguretted sulphurets.

SECT. III.

OF METALLIC HYDROSULPHURETS AND HYDROGURETTED SULPHURETS.

The hydrosulphurets and hydroguretted sulphurets have the property of precipitating all metallic bodies, except rhodium, from any solution in which they may be contained. They are therefore very valuable tests of the presence of metals, as they do not precipitate any of the earths except alumina and zirconia. The metallic precipitates are occasioned by the combination of sulphuretted hydrogen, hydroguretted sulphur, or of sulphur, with the metallic body, which is always deprived of a portion or of the whole of its oxygen, while at the same time the base of the hydrosulphuret combines with the acid which held the oxide in solution. The precipitate of

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* Edin. Phil. Jour. i. 11.

alumina and zirconia is occasioned by the base of the hydrosulphuret, while the sulphuretted hydrogen is exhaled in the state of gas, not being susceptible of combining with these earths. Hydrosulphuret, or hydroguretted sulphuret of potash or ammonia, is usually made choice of for these precipitations; and the peculiar metal precipitated may in many cases be ascertained by the colour of the precipitate. The colour of these different precipitates may be seen by the following table:

Colour of the precipitates.

	Precipitate by	
Metals.	Hydrosulphuret of Potash.	Hydroguretted Sulphuret of Potash.
Gold	Black	Black
Platinum	Black	Black
Silver	Black	Black
Mercury	Brown black	Brown, becoming black
Palladium	Black	
Copper	Black	Brown
Iron	Black	Black, becoming yellow
Nickel	Black	Black
Tin	Black	Black
Lead	Black	White, becoming black
Zinc	White	White
Bismuth	Black	Black
Antimony	Orange	Orange-yellow
Tellurium	Black?	Deep brown or black
Arsenic	Yellow	Yellow
Cobalt	Black	Black
Manganese	White	White
Chromium	Green	
Molybdenum	Reddish brown	
Uranium	Brown	Brownish-yellow[*]
Titanium	Glass green	Bluish-green[*]
Columbium	Chocolate	
Cerium	Brown	

The nature of these precipitates has been very much overlooked by chemists; yet the subject deserves a very particular investigation, as it would enable us to ascertain the nature of the compounds which metals and their oxides form with sulphur and its compounds with hydrogen. The following remarks are all that at present can be offered.

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[*] In these experiments hydrosulphuret of ammonia was used by Klaproth.

1. Almost all the metals combine with sulphur, and form sulphurets which are tasteless, insoluble in water, brittle, and often possess the metallic lustre.*

2. Sulphur reduces many oxides to the metallic state; but with others it seems to combine, and to form compounds which may be called sulphuretted oxides. Three such compounds have been examined and described by chemists; namely sulphuretted oxide of tin, of manganese, and of iron.

Action of sulphuretted hydrogen.

3. Whether sulphuretted hydrogen be capable of combining with metals has not been ascertained. The analogy of other acids would lead us to conclude that it is not; but in chemistry analogies are always dangerous, and generally mislead. The facility with which sulphuretted hydrogen gas tarnishes lead, brass, and silver, is known to all practical chemists; but in these cases the gas seems decomposed, and a simple sulphuret only to be formed. Water impregnated with this gas dissolves some of the metals, especially iron; but it is probable that the metal in these cases is converted into an oxide.

4. It seems to have the property of reducing the greater number of oxides to the metallic state. Hence the reason of the precipitates which it throws down from metallic solutions. The hydrogen of the gas and the oxygen of the oxide mutually unite, while the sulphur and the metal reduced fall down in combination. Most of the metallic precipitates are nothing else than common sulphurets. To this, however, there are several exceptions.

Hydrosulphuret of mercury.

Proust has shown that the red oxide of mercury has the property of decomposing the sulphuretted hydrogen of hydrosulphurets,† while Berthollet has ascertained that the rapidity of the effect depends upon the proportion of the substances employed.‡ When red oxide of mercury is agitated in a liquid hydrosulphuret, a black powder is formed. This black powder, when heated, passes rapidly into cinnabar. The same change takes place slowly if it be exposed to the light. From these facts Berthollet has concluded, that this black powder consists, at least partly, of oxide of mercury and sulphuretted hydrogen, and that by the action of heat the mutual decomposition of the gas and oxide is accelerated. If this be correct, the black powder may be considered as consisting, at least partly, of hydrosulphuret of mercury.

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* See vol. i. p. 409, and Book I. Division I. Chapter IV.

† Jour. de Phys lix. 268.

‡ Ibid. lx. 288.

When sulphuretted hydrogen or a hydrosulphuret is poured into a salt of tin, a precipitate is produced, varying in colour according to the state of oxidizement of the metal. With the peroxide it is a golden yellow; with the protoxide, a dark brown. Proust informs us, that both of these precipitates are hydrosulphurets, or combinations of sulphuretted hydrogen with the respective oxides of tin unchanged. When muriatic acid is poured upon them, the sulphuretted hydrogen is driven off, and muriated tin formed.[*] Of tin.

The following are the metallic hydrosulphurets at present known:

Hydrosulphuret of tin. Both oxides of tin unite with sulphuretted hydrogen: Hydrosulphuretted protoxide is dark brown; hydrosulphuretted peroxide, golden yellow.

Hydrosulphuret of zinc. Zinc is thrown down from acids in the state of a yellowish-white mass by the hydrosulphuret of potash or ammonia. This mass dissolves completely in muriatic acid, and at the same time a great quantity of sulphuretted hydrogen is exhaled. Hence it is obviously a hydrosulphuret. It may be formed also by treating the white oxide of zinc with hydrosulphuret of ammonia.[†] Vauquelin remarks, that the transparent specimens of *native sulphuret of* Blende. *zinc* or *blende* often dissolve in the same way, emitting sulphuretted hydrogen.[‡] It is possible that these specimens approach the nature of hydrosulphuret of zinc. In that case there would be three different kinds of minerals at present confounded under the term *blende;* namely, sulphuret of zinc, sulphuretted oxide of zinc, and hydrosulphuret of zinc. But this must be left for subsequent investigation.

Hydrosulphuret of antimony. When hydrosulphuret of potash, or ammonia is dropped into an acid solution of antimony, a beautiful orange-coloured precipitate falls, which the experiments of Berthollet, Thenard, and Proust have demonstrated to be a hydrosulphuret of antimony. This compound, under the name of *kermes mineral,* acquired very great celebrity Kermes mineral. for its medical virtues about the beginning of the 18th century. The method of preparing it was first discovered by Glauber, and afterwards by Lemery the Elder: but it was first brought into vogue in France by a priest called Simon, who was taught the

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[*] Jour. de Phys. lix. 336.

[†] See Berthollet's Table, Ann. de Chim. xxv. 272.

[‡] Ann. de Chim. xxxvii. 66.

secret of preparing it by La Ligerie, a surgeon, to whom it had been communicated by a pupil of Glauber. The French government purchased the secret from La Ligerie, and published the process in 1720. It was very tedious and ill contrived, consisting in boiling repeatedly a very diluted solution of potash on sulphuret of antimony; a small portion of kermes precipitated as the solution cooled. The process of Lemery was therefore adopted by apothecaries. It is the following:

Sixteen parts of sulphuret of antimony, eight parts of potash of commerce, and one part of sulphur, are triturated together in a mortar, melted in a crucible, and the mass poured into an iron vessel. When cold it is pounded, and boiled in a sufficient quantity of water, and the solution is filtered while hot. On cooling, it deposites the kermes abundantly in the state of a yellow powder, which is edulcorated with a sufficient quantity of water, and dried: Or six parts of potash may be dissolved in twenty parts of water; and to this solution, previously made boiling hot, one part of pounded sulphuret of antimony may be added. The solution, well agitated, boiled for seven or eight minutes, and filtered while hot, deposites on cooling abundance of kermes.

This powder occupied a good deal of the attention of chemists. Bergman first demonstrated that it contained sulphuretted hydrogen; but it was Berthollet who first pointed out its true composition. From the analysis of Thenard, it follows that it is composed of

20·30	sulphuretted hydrogen
4·15	sulphur
72·76	protoxide of antimony
2·79	water and loss
100·00 *	

When this substance is exposed to the air, it gradually absorbs oxygen and becomes white, and the sulphuretted hydrogen exhales.

Sulphur auratum.

After the mineral kermes has precipitated from its solution prepared by either of the formulas above described, if an acid be added to the liquid, another precipitate is produced of an orange colour; hence called *sulphur auratum*. According to the analysis of Thenard, it is composed of

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[*] Ann. de Chim. xxxii. 268.

17·87 sulphuretted hydrogen
68·30 protoxide
12·00 sulphur

98·17 [*]

Hence it is a hydrosulphuret with excess of sulphur and a smaller proportion of base. Goettling has proposed the following process for obtaining this compound: two parts of sulphuret of antimony and three parts of sulphur, well mixed, are dissolved in a boiling solution of pure potash; the solution is then diluted with water, and precipitated by means of a weak sulphuric acid.[†]

If the sulphuret of antimony be deprived of a part of its sulphur by roasting, and the residual matter be boiled, with a solution of soda in water, the liquid on evaporation deposits irregular crystals, which, from the experiments to which I have subjected them, appear to be a hydrosulphuret of soda-and-antimony. They are semitransparent and have a slight shade of red. They dissolve in water. The solution is at first nearly colourless, and when kept in a full and well-stopped phial deposits a fine reddish crust on the inside of the phial; after which the solution undergoes no farther change. When muriatic acid is dropped into the solution a quantity of sulphuretted hydrogen gas is driven off, and a copious precipitate of sulphur auratum falls. This salt has been for some time used by calico printers for striking an orange colour upon cloth.

Hydrosulphuret of manganese. When the black oxide of manganese is treated with sulphuretted hydrogen water, its black colour disappears; a portion of the sulphuretted hydrogen is decomposed at the expense of the oxygen of the black oxide; and the green oxide, thus evolved, is dissolved by the sulphuretted hydrogen, and by evaporation a white mass is obtained, which dissolves completely in muriatic acid, while abundance of sulphuretted hydrogen is exhaled. It is therefore a hydrosulphuret of manganese.[‡] The same compound is obtained when hydrosulphuret of potash is mixed with a salt of manganese.

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[*] Ann. de Chim. xxxii. 268.

[†] Bergman, iii. 172. The experiments of Proust on these compounds are highly interesting, but too long for insertion here. See Jour. de Phys. lv. 323.

[‡] Berthollet, Ann. de Chim. xxv. 238.

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Hydrosulphuret of arsenic. Sulphuretted hydrogen combines with the white oxide of arsenic dissolved in water. The liquid assumes a yellow colour, but no precipitate appears. Hence the hydrosulphuret of arsenic, like that of manganese, is soluble in water, at least by the assistance of an excess of sulphuretted hydrogen. This hydrosulphuret exactly resembles in appearance yellow sulphuret of arsenic.

Hydrosulphuret of iron. Sulphuretted hydrogen combines with the black oxide of iron, and the compound is soluble in water; but the solution soon lets fall a black powder, which is a hydroguretted sulphuret of iron.

Hydrosulphuret of platinum. This substance was first examined with precision by Mr. Edmond Davy, though it had been noticed by preceding chemists. It is obtained by passing a current of sulphuretted hydrogen gas through a solution of platinum in nitro-muriatic acid. It gradually precipitates. When dried without the contact of air its properties are as follows:

It has a dark-brown colour, and little external lustre. Its taste is at first insipid, then saline. When heated just below redness it deflagrates and is partially decomposed. At a red heat it gives out sulphureous fumes, and metallic platinum remains. When heated in close vessels over mercury it gives out water, sulphurous acid gas, sulphuretted hydrogen, a little sulphur, and a substance resembling sulphuret of platinum. The residue is sulphuret of platinum. When heated in acids it gives out gas. When exposed to the air sulphuric acid is formed in it. According to the analysis of Mr. Edmond Davy, its constituents are as follows:[*]

Sulphuret of platinum	83·00
Sulphuretted hydrogen	4·56
Sulphur	4·00
Water impregnated with sulphuretted hydrogen	8·44
	100·00

It is not unlikely that this singular substance may be a compound of 2 atoms of sulphuret of platinum, and 1 atom of sulphuretted hydrogen or hydroguretted sulphur.

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[*] Phil. Mag. xl. 210.

CHAP. IV.

OF SOAPS.

Chap. IV.

THE true nature of soap has been ascertained by the experiments of Chevreul. The fixed oils and tallow, he has shown, consist each of two distinct substances, which he has distinguished by the names *steärin* and *elaïn*. Salifiable bases have the property of altering the composition of these bodies, and of converting them into two acid bodies, to which he has given the appellations of *margaritic acid* and *oleïc acid.* Soaps are nothing else than the combinations of these two acids with salifiable bases.* In the soaps of commerce, both margaritic and oleïc acid usually exist together. The weight of an atom of each of these acids is as follows:

Margaritic acid......	33·3
Oleïc acid	36

So that 100 margaritic acid combine with 18 potash and 12 soda.

100 oleïc acid combine with 16·6 potash and 11·1 soda.

When the bases of soaps are the alkalies, the soaps are soluble in water, and may be employed for the purposes of domestic economy. But when the earths or metallic oxides constitute the bases of soaps, these bodies are insoluble in water, and do not of course answer the purposes of detergents. On this account it will be proper to treat of each set separately.

SECT. I.

OF ALKALINE SOAPS.

As there are a great number of fixed oils, all or most of which are capable of combining with alkalies, earths, and oxides, it is natural to suppose that there are as many genera of alkaline soaps as there are oils. That there are differences in the nature of soaps, corresponding to the oil which enters into their composition, is certain; but these differences are

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* A detailed account of these substances has been given in a preceding chapter of this volume.

not of sufficient importance to require a particular description. It will be sufficient therefore to divide the alkaline soaps into as many species as there are alkalies, and to consider those soaps which have the same alkaline base, but differ in their oil, as varieties of the same species.

Sp. 1. *Soap of Soda*, or *Hard Soap.*

History.

The word *soap* (*sapo*, *σαπον*) first occurs in the works of Pliny and Galen, and is evidently derived from the old German word *sepe.*[*] Pliny informs us that soap was first discovered by the Gauls; that it was composed of tallow and ashes; and that the German soap was reckoned the best.[†]

Preparation.

Soap may be prepared by the following process: a quantity of the soda of commerce is pounded and mixed in a wooden vessel with about a fifth part of its weight of lime, which has been slacked and passed through a sieve immediately before. Upon this mixture a quantity of water is poured, considerably more than what is sufficient to cover it, and allowed to remain on it for several hours. The lime attracts the carbonic acid from the soda, and the water becomes impregnated with the pure alkali. This water is then drawn off by means of a stop-stock, and called the *first ley*. Its specific gravity should be about 1·200.

Another quantity of water is then to be poured upon the soda, which, after standing two or three hours, is also to be drawn off by means of the stop-stock, and called the *second ley.*

Another portion of water is poured on; and after standing a sufficient time, is drawn off like the other two, and called the *third ley.*

Another portion of water may still be poured on, in order to be certain that the whole of the soda is dissolved; and this weak ley may be put aside, and employed afterwards in forming the first ley in subsequent operations.

A quantity of oil, equal to six times the weight of the soda used, is then to be put into the boiler, together with a portion of the *third* or *weakest ley;* and the mixture must be kept boiling and agitated constantly by means of a wooden instrument. The whole of the third ley is to be added at intervals to the mixture; and after it is consumed, the *second ley* must

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[*] Beckmann's History of Inventions, iii. 239. A similar word is still used by the common people of Scotland.

[†] Pliny, lib. xviii. 51.

be added in the same manner. The oil becomes milky, combines with the alkali, and after some hours it begins to acquire consistence. A little of the *first ley* is then to be added, not forgetting to agitate the mixture constantly. Portions of the first ley are to be added at intervals; the soapy substance acquires gradually greater consistency, and at last it begins to separate from the watery part of the mixture. A quantity of common salt is then to be added, which renders the separation much more complete. The boiling is to be continued still for two hours, and then the fire must be withdrawn, and the liquor must be no longer agitated. After some hours repose, the soap separates completely from the watery part, and swims upon the surface of the liquor. The watery part is then to be drawn off; and as it contains a quantity of carbonate of soda, it ought to be reserved for future use.

The fire is then to be kindled again; and, in order to facilitate the melting of the soap, a little water, or rather weak ley, is to be added to it. As soon as it boils, the remainder of the first ley is to be added to it at intervals. When the soap has been brought to the proper consistence, which is judged of by taking out small portions of it and allowing it to cool, it is to be withdrawn from the fire, and the watery part separated from it as before. It is then to be heated again, and a little water mixed with it, that it may form a proper paste. After this let it be poured into the vessels proper for cooling it; in the bottom of which there ought to be a little chalk in powder, to prevent the soap from adhering. In a few days the soap will have acquired sufficient consistence to be taken out, and formed into proper cakes.*

The use of the common salt in the above process is to separate the water from the soap; for common salt has a stronger affinity for water than soap has.

Olive oil has been found to answer best for making soap, and next to it, perhaps, tallow, might be placed: but a great variety of other oils may be employed for that purpose, as appears from the experiments of the French chemists above quoted. They found, however, that linseed oil and whale oil were not proper for making *hard soaps*, though they might be employed with advantage in the manufacture of *soft soaps*. Whale oil has been long used by the Dutch for this last purpose.

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* See the Memoir of Darcet, Lelievre, and Pelletier, in the Ann. de Chim. xix. 253.

Soaps may also be made without the assistance of heat; but in that case a much longer time and a larger proportion of alkali is necessary.

Composition.

The hard soap of commerce varies so much in its proportion of water that it is impossible to state its composition with accuracy. Supposing no adulteration, its constituents will be nearly as follows:

1 atom margaritic and oleïc acids	64·49
1 atom soda	7·57
28 atoms water	27·94
	100·00

As the proportion of water increases, that of the other constituents of course diminishes. I have met with soap composed as follows:

1 atom oily acid	44·63
1 atom soda	5·24
68 atoms water	50·13
	100·00

The purchaser of such a soap pays half of his money for water. From the experiments of Colin, it appears that water is essential to the fabrication, and probably to the constitution of soap. But the proportion usually found in soap seems excessive.

Soap is soluble both in water and in alcohol. Its properties as a detergent are too well known to require any description.

Soap made with tallow and soda has a white colour, and is therefore known by the name of *white* soap: but it is usual for soap-makers, in order to lower the price of the article, to mix a considerable portion of rosin with the tallow; this mixture forms the common *yellow soap* of this country.

Sp. 2. *Soap of Potash,* or *Soft Soap.*

Formation.

Potash may be substituted for soda in making soap, and in that case precisely the same process is to be followed. It is remarkable, that when potash is used, the soap does not assume a solid form; its consistence is never greater than that of hog's lard. This is what in this country is called *soft soap.* Its properties as a detergent do not differ materially from those of *hard soap,* but it is not nearly so convenient for use. The alkali employed by the ancient Gauls and Germans in the formation of soap was potash; hence we see the reason that it is described by the Romans as an unguent. The oil employed for making soft soap in this country is whale oil. A little tallow is also added, which, by peculiar management, is dispersed through the soap in fine white spots.

Some persons have affirmed that they knew a method of making hard soap with potash. Their method is this: after forming the soap in the manner above described, they add to it a large quantity of common salt, boil it for some time, and the soap becomes solid when cooled in the usual way. That this method may be practised with success has been ascertained by Messrs. Darcet, Lelievre, and Pelletier: but then the hard soap thus formed does not contain potash but soda; for when the common salt is added, the potash of the soap decomposes it, and combines with its muriatic acid, while at the same time the soda of the salt combines with the oil, and forms hard soap: and the muriate of potash formed by this double decomposition is dissolved in water, and drawn off along with it.*

Sp. 3. *Soap of Ammonia.*

This soap was first particularly attended to by Mr. Berthollet. It may be formed by pouring carbonate of ammonia on soap of lime. A double decomposition takes place, and the soap of ammonia swims upon the surface of the liquor in the form of an oil; or it may be formed with still greater ease by pouring a solution of muriate of ammonia into common soap dissolved in water.

It has a more pungent taste than common soap. Water dissolves a very small quantity of it; but it is easily dissolved in alcohol. When exposed to the air, it is gradually decomposed. The substance called *volatile liniment*, which is employed as an external application in rheumatisms, colds, &c. may be considered as scarcely any thing else than this soap.

All the alkaline soaps agree in the properties of solubility in water and alcohol, and in being powerful detergents.

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* Ann. de Chim. xix. 322.

SECT. II.

OF EARTHY SOAPS.

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The earthy soaps differ essentially from the alkaline in their properties. They are insoluble in water, and incapable of being employed as detergents. They may be formed very readily by mixing common soap with a solution of an earthy salt: the alkali of the soap combines with the acid of the salt, while the earth and oil unite together and form an earthy soap. Hence the reason that all waters holding an earthy salt are unfit for washing. They decompose common soap, and form an earthy soap insoluble in water. These waters are well known by the name of *hard* waters. Hitherto the earthy soaps have been examined by Berthollet and Chevreul only.

Sp. 1. *Soap of Lime.*

This soap may be formed by pouring lime-water into a solution of common soap. It is insoluble both in water and alcohol. Carbonate of fixed alkali decomposes it by compound affinity.* It melts with difficulty, and requires a strong heat.

Soap of barytes and of strontian resemble almost exactly the soap of lime.

Sp. 2. *Soap of Magnesia.*

This soap may be formed by mixing together solutions of common soap and sulphate of magnesia. It is exceedingly white. It is unctuous, dries with difficulty, and preserves its whiteness after desiccation. It is insoluble in boiling water. Alcohol and fixed oil dissolve it in considerable quantity. Water renders its solution in alcohol milky. A moderate heat melts it; a transparent mass is formed, slightly yellow, and very brittle.†

Sp. 3. *Soap of Alumina.*

This soap may be formed by mixing together solutions of alum and of common soap. It is a flexible soft substance, which retains its suppleness and tenacity when dry. It is in-

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* Thouvenel.

† Berthollet, Mem. Par. 1780, or Nicholson's Jour. i. 170.

soluble in alcohol, water, and oil. Heat easily melts it, and reduces it to a beautiful transparent yellowish mass.*

SECT. III.

OF METALLIC SOAPS AND PLASTERS.

Metallic oxides are capable of combining with oils by two different processes: 1. By mixing together a solution of common soap with a metallic salt: 2. By uniting the metallic oxide with the oil directly, either cold or by the assistance of heat. The first of these combinations is called a *metallic soap;* the second a *plaster.* Let us consider each of these in their order.

I. *Metallic Soaps.*

These soaps have been examined by Mr. Berthollet, who has proposed some of them as paints, and others as varnishes; but it does not appear that any of them has been hitherto applied to these purposes.

1. *Soap of mercury* may be formed by mixing together a solution of common soap and of corrosive muriate of mercury. The liquor becomes milky, and the soap of mercury is gradually precipitated. This soap is viscid, not easily dried, loses its white colour when exposed to the air, and acquires a slate colour, which gradually becomes deeper, especially if exposed to the sun or to heat. It dissolves very well in oil, but sparingly in alcohol. It readily becomes soft and fluid when heated.†

2. *Soap of zinc* may be formed by mixing together a solution of sulphate of zinc and of soap. It is of a white colour, inclining to yellow. It dries speedily, and becomes friable.‡

3. *Soap of cobalt,* made by mixing nitrate of cobalt and common soap, is of a dull leaden colour, and dries with difficulty, though its parts are not connected.

Mr. Berthollet observed, that towards the end of the precipitation there fell down some green coagula, much more consistent than soap of cobalt. These he supposed to be a soap of nickel, which is generally mixed with cobalt.§

4. *Soap of tin* may be formed by mixing common soda with

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* Berthollet, Mem. Par. 1780, or Nicholson's Jour. i. 170.

† Ibid. ‡ Ibid. § Ibid.

a solution of tin in nitro-muriatic acid. It is white. Heat does not fuse it like other metallic soaps, but decomposes it.*

5. *Soap of iron* may be formed by means of sulphate of iron. It is of a reddish-brown colour, tenacious, and easily fusible. When spread upon wood, it sinks in and dries. It is easily soluble in oil, especially of turpentine. Berthollet proposes it as a varnish.†

6. *Soap of copper* may be formed by means of sulphate of copper. It is of a green colour, has the feel of a resin, and becomes dry and brittle. Hot alcohol renders its colour deeper, but scarcely dissolves it. Ether dissolves it, liquefies it, and renders its colour deeper and more beautiful. It is very soluble in oils, and gives them a pleasant green colour.‡

7. *Soap of lead* may be formed by means of acetate of lead. It is white, tenacious, and very adhesive when heated. When fused it is transparent, and becomes somewhat yellow if the heat be increased.§

8. *Soap of silver* may be formed by means of nitrate of silver. It is at first white, but becomes reddish by exposure to the air. When fused, its surface becomes covered with a very brilliant iris; beneath the surface it is black.‖

9. *Soap of gold* may be formed by means of muriate of gold. It is at first white, and of the consistence of cream. It gradually assumes a dirty purple colour, and adheres to the skin, so that it is difficult to efface the impression.**

10. *Soap of manganese* may be formed by means of sulphate of manganese. It is at first white, but it assumes in the air a reddish colour, owing evidently to the absorption of oxygen. It speedily dries to a hard brittle substance, and by liquefaction assumes a brown-blackish colour.††

II. *Plasters.*

Properties.

Plasters are combinations of oils and metallic oxides destined to be spread upon leather or cloth, and in that state to be applied as a covering of ulcers, &c. They ought to be solid bodies, not so hard as to refuse to spread easily and equally, nor so soft as to run into oil when heated by the skin. They ought to admit of being easily kneaded when heated with the hand, to adhere firmly to the skin, but to be capable of being re-

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* Berthollet, Mem. Par. 1780, or Nicholson's Jour. i. 170.

† Ibid.

‡ Ibid.

§ Ibid.

‖ Ibid.

** Ibid.

†† Ibid.

moved without leaving behind them any stain. Without these properties they do not answer the purpose for which they are destined, which is chiefly adhesion.

The only chemist who has hitherto examined plasters with attention is Deyeux, to whom we are indebted for some excellent observations on the method of preparing them.*

Oxides used.

The oxides hitherto employed for making plasters are those of lead; and *litharge* is usually considered as the best adapted for that purpose of any of these oxides. But the oxides of several of the other metals, as bismuth and mercury, are also capable of forming plasters, and might perhaps in some cases be employed with advantage. Some metallic oxides, however, as those of iron, are not susceptible of that kind of combination with oils which constitutes plasters.†

Oils.

All the fixed oils are capable of forming plasters; but they do not all form plasters with the same properties. The *drying* oils, linseed oil for instance, form plasters of a much softer consistency than the *fat* oils: but these last acquire the same properties as the drying oils if they be combined with mucilage. Thus, olive oil, boiled for some time with linseed or fenugree, forms with litharge plasters as soft as those composed of linseed oil and litharge. According to Deyeux, olive oil answers better for plasters than any other.

Formation.

1st Process.

There are three different ways of forming plasters. The first consists in simply mixing together oil and litharge in proper proportions, and allowing the mixture to remain a considerable time in the common temperature of the atmosphere, agitating it occasionally. The oxide gradually loses its colour and combines with the oil, and the mixture acquires consistence. This process is tedious, and does not furnish plasters sufficiently solid to answer the purposes for which they are intended. It is not therefore employed.

2d Process.

The second method consists in throwing the oxide into the oil while boiling. Plasters formed by this process have always a deep colour and a peculiar odour, occasioned by the decomposition of a portion of the oil. When this process is followed, it is necessary that the oxide should be in the state of a fine powder; and that by agitation it should be made to combine with the oil as fast as possible, otherwise the metal will be revived altogether, in consequence of the strong tendency

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* Ann. de Chim. xxxiii. 50.

† Deyeux, Ann. de Chim. xxxiii. 50.

which oil has to combine with oxygen when raised to a high temperature.

3d Process. The third method is most frequently practised, because it is not liable to the same inconveniences as the other two. This method consists in boiling the oil and the oxide together in a sufficient quantity of water. By this liquid the heat is moderated at first till the oil and oxide combine, which prevents the revival of the metal; and afterwards when the water is dissipated, the temperature is sufficiently high to give the plaster the requisite consistency.

Plasters, when long kept, become often too hard to be fit for use, especially if the requisite proportion of oil has not been employed at first. This defect is easily remedied, by melting them with a small portion of new oil. Plasters, when long kept, likewise change their colour, and most of their sensible properties: owing either to the absorption of oxygen, or to some change produced in their component parts by the action of the air.

CHAP. V.

GENERAL REMARKS.

If we exclude the compound combustibles, the nature of which has not been hitherto sufficiently studied, all the primary compounds, with a few exceptions indeed, may be divided into the two grand classes of *acids* and *bases*. All the secondary compounds described in the preceding chapters, except the hydrates, may be considered as combinations of *acids* and *bases*. The hydrates indeed have been considered by some modern chemists, as likewise saline combinations. But this name cannot be applied to them without extending the meaning of the terms *acid* and *base* so far as to render them really useless. For in the hydrates we must consider the *water* as sometimes acting the part of an acid, and sometimes of a base. While in the crystallized salts, as in *sulphate of soda*, it would be impossible either to apply the term *acid* or *base* to the water without manifest impropriety. It seems much better, therefore, to consider hydrates as a species of compound quite different from *salts*. The water is capable equally of uniting with *acids*, *bases*, and *salts*. It does not deprive them of their characteristic properties, or *neutralize* them as the bases do the acids. As far as we know at present, water is capable of uniting with other bodies in a greater number of proportions than either acids or bases. Scarcely any of the acids or bases have been found united with other bodies in a greater proportion than 4 atoms. But some salts contain no fewer than 36 atoms of water. Sophisticated soap sometimes contains no fewer than 68 atoms of water to one of the true soap.

The salts, the hydrosulphurets, and soaps are true saline compounds, though sufficiently distinct from each other to deserve a separate place in every chemical arrangement. Soaps do not crystallize or assume regular forms. Hydrosulphurets crystallize, but they cannot be preserved in contact with the atmosphere without undergoing a series of changes, which have not been sufficiently examined. Hereafter the hydrotellurets will form a set of bodies analogous to the hydrosulphurets. I have little doubt that a careful examination of them would throw considerable light on the changes which the hydrosulphurets undergo.

Several of the secondary compounds, as common salt, nitre, green vitriol, &c. are found ready formed by nature. It was by studying their properties that the science of chemistry first originated. They furnished some of the most powerful reagents which have been applied to the investigation of the composition of natural bodies; such as nitric acid, muriatic acid, sulphuric acid, soda, &c.

Secondary compounds resemble simple bodies.

Few of the secondary compounds have that activity, that violent action upon other bodies, which distinguish the primary compounds. In this respect they bear a strong resemblance to the simple substances. Sulphur, for instance, is a body which has scarcely any taste, and which acts but feebly upon animals, and not at all perceptibly upon vegetables and minerals; and oxygen, though it undoubtedly merits the appellation of an active body, shows neither in its taste nor in its action on animals and vegetables, any thing which deserves the name of acrid or caustic; but sulphuric acid, though composed of these two inoffensive bodies, is one of the most active and corrosive substances known, and burns and decomposes almost all the animal and vegetable bodies which are exposed to its influence. Potash is, if possible, still more corrosive; even the hardest mineral is unable to resist its action. But sulphate of potash, though composed of these two formidable bodies, is not more active than sulphur itself. This singular correspondence between simple substances and secondary

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compounds, and the striking contrast between them and the primary compounds, deserve attention. It demonstrates to us, that the activity of bodies is not proportional to their simplicity, as has been hitherto supposed; and that there is some other cause, besides combination with other bodies, to blunt their energy.

None of them gases.

Several of the simple bodies exist commonly in the state of gas: this is the case also with the primary compounds; but no gaseous body is found among the secondary compounds, and only a comparatively small number of liquid bodies. Almost all of them are solid, and probably every one of them is susceptible of assuming that form. Hence we see that gaseous bodies have all of them a considerable degree of simplicity; few of them, as far as is known, containing more than two component parts, if we omit the consideration of light and caloric altogether; or three component parts, if we include these bodies.

END OF VOL. II.

C. Baldwin, Printer,
New Bridge-street, London.