A

SYSTEM

OF

CHEMISTRY.

IN FOUR VOLUMES.

BY THOMAS THOMSON, M. D.
LECTURER ON CHEMISTRY IN EDINBURGH.

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VOLUME THIRD.

A
SYSTEM
OF
CHEMISTRY.

DIVISION II. OF BOOK II. CONTINUED.

GENUS VII. SALTS OF IRON.

Chap. III.

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. No metal attracts oxygen and combines 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 basis; 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 *oxy-sulphat of iron.* Since that time Mr Davy has ascertained the existence of several more of these salts.

The salts of iron may be distinguished by the following properties:

Characters.

1. They are almost all soluble in water; and in general the solution has a greenish or yellowish red colour, and an astringent taste.

2. The triple prussiats occasion in these solutions a precipitate of a deep blue, or at least which acquires that colour on exposure to the atmosphere.

3. Hydro-sulphuret of potass occasions a black precipitate.

4. Sulphurated hydrogen renders the solution nearly colourless, but occasions no precipitate.

5. Gallic acid, or the infusion of nutgalls, occasions a black or purple precipitate, at least if the solution has been for some time exposed to the air.

Sp. 1. *Sulphated Iron.*

Concentrated sulphuric acid acts but very slowly upon iron, unless it be assisted by heat. In that case the metal is oxidated, 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 *sulphat* of iron; but if allowed to remain exposed to the atmosphere, it gradually attracts more oxygen, and is converted into *oxysulphat*, unless it contains an excess of acid; which retards, and when sufficiently abundant, prevents the change.

Preparation.

1. *Sulphat 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 sulphurets of iron, which are found native in abundance, and exposing them to the open air. They are slowly covered with a crust of sulphat of iron, 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.

Properties.

Sulphat 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;

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[*] Lib. xxxiv. c. 12.

[†] Hauy, *Jour. de Min.* An. v. 542.

[‡] Hassenfratz, *Ann. de Chim.* xxviii. 12.

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because it absorbs oxygen, and is partially converted into oxy-sulphat. 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 sulphurous acid is driven off, and there remains behind a red powder, formerly known by the name of *colcothar of vitriol*, which seems to be a mixture of brown oxide of iron and oxy-sulphat. 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, and which is now known to be a compound of sulphuric and sulphurous acids. The residuum is the same mixture of oxide and oxy-sulphat which is obtained by calcination in the open fire. This decomposition, which sulphat of iron undergoes when heated, enables it in many cases, in a high temperature, to act nearly the same part as sulphuric acid. Hence it is often employed by manufacturers to disengage the weaker acids from their bases.

Composition.

This salt, according to Bergman, is composed of

39 acid
23 oxide
38 water

100 [*]

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[*] *Opusc.* i. 137.

According to Kirwan, of 26 acid
28 oxide
8 water of composition
38 water of crystallization
100 *

It cannot be doubted, I think, that the black oxide of iron is capable of combining intimately with water, and of forming a *hydrat*, as well as the oxide of copper. The colour of this hydrat is *green;* hence the reason that the black oxide of iron, when precipitated from acids by means of alkalies, has a green colour. It is in the state of hydrat. When the water is driven off by heat, the oxide assumes its natural black colour. The oxide, which constitutes a part of the sulphat of iron, is also combined with water, and in the state of a hydrat. Mr Kirwan, therefore, has, with great propriety, distinguished between the water of crystallization and that part which is a necessary constituent of the salt.

The sulphat of iron is decomposed by the alkaline phosphats and borats, and by the greater number of those salts whose base forms an insoluble compound with the sulphuric acid, as nitrat of silver, of lead, of barytes, &c.

2. *Oxy-sulphat of iron.* This salt exists ready formed in what is called the *mother water of vitriol*, or the brown liquid which remains after all the sulphat of iron has been extracted by crystallization from those waters which contain it. The properties of this salt were first accurately described by Mr Proust. It may be formed by exposing the solution of sulphat of iron to the open air

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* *On Mineral Waters*, Table iv.

for some time, or by pouring into it nitric acid, and applying heat *.

This salt has a red colour. It does not afford crystals; and when evaporated to dryness, soon attracts moisture, and becomes again liquid. It is exceedingly soluble in water, and also in alcohol. By this last liquid it may be separated from the sulphat of iron, with which it is always mixed in the *vitriol* of commerce. When exposed to the air, it gradually deposites red oxide, or rather oxy-sulphat with excess of base.

How changed into sulphat,

A great number of substances have the property of depriving this salt of its excess of oxygen, and of converting it into sulphat of iron. This is the case with iron. When the solution of oxy-sulphat is mixed with iron-filings, and kept for some time in a well-covered vessel, part of the iron is dissolved by abstracting the second dose of oxygen from the oxide, and the whole is converted into sulphat. The same change is produced by tin, and probably also by all the salts of tin which contain that metal combined with a minimum of oxygen. Sulphurated hydrogen produces that change instantaneously when made to pass through a solution of oxy-sulphat †. That gas has the property of reducing the oxides of iron to a minimum of oxygen; but it does not bring them to the metallic state. Hence the reason that it does not precipitate iron from its solution in acids.

On the other hand, all those bodies which part with oxygen very readily, convert the sulphat of iron into

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* During this change a quantity of ammonia is also formed. Hence not only the nitric acid but some water also is decomposed.—See Davy's *Researches*, p. 157.

† Proust, *Ann. de Chim.* xxiii. 23.

oxy-sulphat. Hence this change is produced by the nitric and oxy-muriatic acids, by the oxy-muriats, the muriat of gold, &c.

Absorption of nitrous gas.

The solution of sulphat of iron has the property of absorbing a great quantity of nitrous gas, and at the same time it acquires a yellowish colour. When this solution is heated without being exposed to the air, the greatest part of the nitrous gas is driven off unchanged; but a small portion of it is decomposed, a little red oxide of iron is precipitated, and some ammonia formed, owing to the decomposition of a little of the water of the solution, and the combination of its hydrogen with the azot of the nitrous gas. From the experiments of Mr Davy, it appears that 910 parts of a solution of sulphat of iron, of the specific gravity 1.4, absorb 5.72 parts of nitrous gas; 4.28 of these are emitted unaltered on the application of heat, and 1.44 are decomposed. This ingenious gentleman calculates that 1 part of water was also decomposed; that the oxygen furnished by these two bodies amounted to 1.65, and that it combined with 4.1 parts of black oxide, and occasioned the precipitation of 5.75 parts of brown oxide, which was doubtless in the state of oxy sulphat, with excess of base. Hence the ammonia formed must have amounted to about 0.8 *. The oxy-sulphat of iron has not the property of absorbing nitrous gas †.

Sp. 2. *Sulphite 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,

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* Davy's *Researches*, p. 170. † Ibid.

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During this solution no hydrogen gas is emitted except a few bubbles at first. The iron is oxidated at the expence of the acid, part of which is decomposed; its oxygen combines with the iron and converts it into black oxide, while its sulphur combines with the sulphite of iron as it forms. The salt, therefore, which is obtained by this process, is not pure sulphite of iron, but that salt combined with sulphur. These phenomena were first described by Berthollet *. When sulphuric acid or muriatic acid is poured into this solution the sulphurous acid is disengaged with effervescence; and if these acids be added in sufficient quantity a portion of sulphur is precipitated.

When the solution is exposed to the air, crystals of sulphite of iron are formed, and at the same time a red powder is deposited, probably consisting of *oxy-sulphite* of iron with excess of base, and combined with sulphur. The crystals dissolved in water and exposed to the air are gradually converted into sulphat of iron. †.

Thus there are two varieties of sulphited iron, *simple sulphite* and *sulphurated sulphite*. The first of these is insoluble in alcohol; but that liquid dissolves the second: the first, when exposed to the air, is converted into sulphat, but the second remains unaltered ‡.

Sp. 3. *Nitrated iron.*

Nitric acid acts with great energy upon iron, a violent effervescence takes place, nitrous gas is emitted in abundance, the iron is generally oxidated to a maximum, and a red powder precipitates, consisting probably of oxy-nitrat with excess of base. These phenomena have been long known; but it was not till after

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* *Ann. de Chim.* ii. 58.

† Fourcroy, vi. 200.

‡ Ibid.

Mr Proust's *Researches on the Prussiats 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 *oxy-nitrat* of iron which is obtained by the usual process. Mr Proust merely announced the existence of the simple nitrat, but it has since been examined by Mr Davy.

Formation.

1. *Nitrat 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 oxidated to a minimum. This solution absorbs nitrous gas. It cannot be concentrated, nor even heated, without being converted into oxy-nitrat *.

2. *Oxy-nitrat of iron.* This is the salt obtained when iron is treated with strong nitric acid, or when the nitrat is heated or left exposed to the air. The solution is of a brown colour, and cannot be crystallized. 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 evaporated to dryness, the acid is disengaged, and the oxide remains in the form of a fine red powder, insoluble in nitric acid. Hence solution in nitric acid, evaporating to dryness, and digesting the residuum in water, is the method recommended by Bergman, and commonly prac-

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* Davy's *Researches*, p. 187.

tised by chemists to separate iron from earths. The iron and earths are first dissolved together in nitric acid; by the evaporation to dryness, the nitrat of iron is de-decomposed, while the earthy nitrats remain unaltered. They are of course dissolved by the water, but the red oxide of iron is left untouched.

How crystallized.

Vauquelin has lately discovered a method of obtaining the oxy-nitrat 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 *.

Sp. 4. *Muriated Iron.*

MURIATIC ACID attacks iron even with more rapidity than the sulphuric; hydrogen gas is emitted in consequence of the decomposition of water, and the iron is oxidated and dissolved. This acid dissolves likewise the oxides of iron much more readily than any other, and for that reason it is usually 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 brown oxides of iron, and forms with each of them a peculiar salt, the properties of which have been lately described by Mr Davy. Their existence had been previously pointed out by Proust. The common muriat

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* Fourcroy, vi. 205.

of iron, usually obtained by dissolving iron or its oxides in muriatic acid, is a mixture of these two salts.

1. *Muriat 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 muriat of iron almost white, which are extremely soluble in water, but insoluble in alcohol. The solution attracts oxygen from the air and from nitric acid. It absorbs nitrous gas even in greater quantity than sulphat of iron, and acquires, when saturated, a dark brown colour, and a much more astringent taste than muriat 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 sulphat of iron impregnated with nitrous gas*.

2. *Oxy-muriat of iron.* This salt may be formed by dissolving the red oxide of iron in muriatic acid, or by treating the muriat of iron with nitric acid. The solution of this salt is of a deep brown; its odour is peculiar, and its taste, even when much diluted 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 oxy-muriatic acid. When sulphuric acid is poured upon it, the odour of oxy-muriatic acid is perceptible. This salt does not absorb nitrous gas. When sulphurated hydrogen gas is made to pass through it, part of the oxygen is abstracted, and the salt is converted into muriat of iron †.

Action on animals and vegetables.

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* Davy, p. 180.

† Ibid. p. 181.

When this salt is distilled, oxy-muriatic acid passes over, and the iron is reduced to the state of black oxide. This acid is also formed and exhaled during the solution of brown oxide of iron in muriatic acid, at least if the solution be promoted by the application of heat.

Sp. 5. *Phosphated 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 oxidated, and converted into phosphat of iron. The properties of phosphated iron have not been examined with attention. Scheele has shewn that the acid combines with both oxides, and forms of course both a *phosphat* and *oxy-phosphat* of iron. Fourcroy and Vauquelin have lately 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 *sub-oxy-phosphat*, which these philosophers first observed.

1. *Phosphat of iron.* When sulphat of iron dissolved in water is mixed with a solution of phosphat of potass, a blue powder precipitates, which is phosphat 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 analysed by Klaproth. *Native prussian blue*, as it is called, when dry out of the earth,

Native prussian blue.

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* Scheele, Crell's *Annals*, i. 115. Engl. Trans.

is at first often colourless; but when exposed to the air, it becomes blue. The cause of this change has not been ascertained.

2. *Oxy-phosphat of iron.* This salt may be readily procured by mixing together the solutions of oxy-muriat of iron and phosphat of potass or soda. A white powder immediately falls, which is oxy-phosphat of iron.

This salt, like almost all the phosphats, 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 one part of oxy-phosphat. 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. *Sub-oxy-phosphat of iron.* When the oxy-phosphat 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 oxy-phosphat with excess of base. This salt is scarcely soluble in acids or in water; but it dissolves readily in the white of an egg, or in the serum of blood, and communicates to these liquids a brown or red colour. Its solubility is increased, and its colour heightened, by the presence of a portion of fixed alkali†. This is the salt which gives a red colour to the blood.

Sp. 6. *Fluated Iron.*

Fluoric acid attacks iron with violence; hydrogen

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* Bergman, iii. 118.

† Fourcroy, ix. 152.

gas is emitted, and the metal oxidated and dissolved. The solution has an inky taste, and when evaporated does not crystallize, but assumes the form of a jelly. In this state it is undoubtedly an *oxy-fluat* of iron. Heat decomposes it by expelling the acid. The same effect is produced by sulphuric acid. Fluoric acid also dissolves the brown oxide of iron, and forms the same salt *.

Sp. 7. *Borat of Iron.*

Boracic acid acts very feebly upon iron; but borat of iron may be obtained very readily by pouring liquid borat of soda into a solution of sulphat of iron. A pale yellow powder immediately precipitates, which is the salt required. This salt is insoluble in water. Before the blow-pipe it melts readily into a globule of glass †.

Sp. 8. *Carbonat 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 black oxide ‡. This carbonat often exists native in mineral waters. It may be obtained also by precipitating sulphat of iron by means of an alkaline carbonat. In that case it is always in the form of a green mass.

Rust may be considered as an oxy-carbonat of iron; for it consists of the brown oxide of that metal combi-

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* Scheele, i. 34.

† Id. Crell's *Annals*, i. 114. Engl. Trans.

‡ Bergman, i. 33.

ned 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*. From the experiments of Bergman carbonat of iron seems to be composed of about 24 acid
76 oxide

100†

Sp. 9. *Arseniated 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 *arseniat* of iron and *ox-arseniat* of iron. Both of these salts have been found native in Cornwall, and have been lately described and analysed with great accuracy by Bournon and Chenevix.

1. *Arseniat of iron.* This salt may be formed by pouring arseniat of ammonia into sulphat 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

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* Fourcroy, vi. 215.

† Bergman, ii. 392.

‡ Scheele, i. 177.

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 arseniat, according to the analysis of Chenevix, is

Composition.

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 †

2. *Ox-arseniat of iron.* This salt may be formed by precipitating oxy-sulphat of iron with arseniat of ammonia, or by boiling the arseniat of iron in nitric acid. The native arseniat 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 ox-arseniat is composed of 42.4 acid
37.2 oxide
20.4 water

100.0 ‡

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* Bournon, *Phil. Trans.* 1801, p. 190.

† Ibid. p. 220.

‡ Ibid. p. 223.

Sp. 10. *Tungstat of Iron.*

THIS salt exists native, and is known to mineralogists by the name of *Wolfram*. It may be formed by precipitating sulphat of iron by means of the tungstats. It is an insoluble powder, possessing properties similar to native tungstat of iron. As this native salt contains also manganese, and is not therefore a pure tungstat of iron, it will be proper to defer the description of it to the SECOND PART of this Work.

Sp. 11. *Molybdat of Iron.*

THE alkaline molybdats precipitate iron brown from its solution in acids*.

Sp. 12. *Acetite of Iron.*

THE acetous 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 properties of these salts have not been examined with attention.

Acetite of iron 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 *oxacetite*.

Oxacetite 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 calicoe printers, because it is more easily decomposed than any other of the oxigenated salts of

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* Scheele, i. 248.

† Hassenfratz, *Ann. de Chim.* xxxviii. 12.

iron. They prepare it either by mixing together sulphat of iron and acetite of lead, and leaving the solution exposed to the air, or by dissolving iron in an impure acetous acid, obtained by distilling wood.

The acetites of iron are decomposed by heat, and the iron left in the state of black oxide.

Sp. 13. *Oxalated Iron.*

OXALIC ACID attacks iron rapidly, and dissolves it with effervescence and forms a peculiar salt with each of its oxides.

Oxalat 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

Oxygenated oxalat 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 oxide of iron even when combined with gallic acid. Hence it is often used to take spots of ink out of linen; and super-oxalat of potass is usually sold in this country for that purpose, under the name of *essential salt of lemons*.

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* Bergman, i. 268.

Sp. 14. *Tartrited Iron.*

TARTAROUS ACID dissolves iron with effervescence, and combines with each of its oxides.

Tartrite of iron may be formed, according to Retzius, by pouring tartarous acid into sulphat of iron, and applying heat to the solution. Lamellar crystals are formed, sparingly soluble in water, which possess the properties of tartrite of iron.

Oxy-tartrite is usually formed when iron is dissolved in tartarous 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. 15. *Triple Tartrite of Iron.*

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 up into a paste, in a proper quantity of water. The liquor by evaporation deposites crystals, which form the salt wanted.

Sp. 16. *Citrat of Iron.*

THIS salt has only been examined by Vauquelin. Citric acid dissolves iron slowly; the solution has a brown colour, and deposites small crystals of citrat of iron. When evaporated, it becomes black like ink, ductile while hot, but brittle while cold. This mass is evidently oxy-citrat of iron. It is astringent, and very soluble in water.

Citrat of iron, according to Vauquelin, is composed of . . . . 69.62 acid

30.38 oxide

100.00 [*]

Sp. 17. *Malat of Iron.*

A BROWN solution not crystallizable [†].

Sp. 18. *Gallat of Iron.*

Writing ink.

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 gallat 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 oxigenated 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 this solution which constitutes writing *ink*. But ink is usually made by mixing the sulphat of iron of commerce with a saturated solution of nutgalls. Now the sulphat of commerce is a mixture of sulphat and oxy-sulphat of iron. That part of the iron which is in the state of sulphat 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

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[*] Fourcroy, vii. 209.

[†] Scheele, Crell's *Annals*, ii. 10. Engl. Trans.

when the writing dries, in consequence of the absorption of oxygen.

Gallat 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. 19. *Benzoat of Iron.*

THIS salt forms yellow crystals. It has a sweet taste. It is soluble in water and alcohol. It effloresces in the air. Heat disengages the acid *.

Sp. 20. *Succinat of Iron.*

SUCCINIC ACID dissolves the oxide of iron, and yields by evaporation small brown transparent radiated crystals †.

Sp. 21. *Prussiated Iron.*

THE combination formed between the prussic acid and iron has been the object of a great many researches, and has given occasion to several curious and important discoveries. We are indebted to Mr Proust for the fact that the prussic acid, like all other acids hitherto tried, is capable of forming a peculiar salt with each of the oxides of iron.

1. *Prussiat of iron.* This salt may be formed by pouring triple prussiat of potass into a solution of sulphat of iron. The salt precipitates in the form of a white powder. It is not altered by sulphuric and muriatic acids. When exposed to the air it absorbs oxygen with great rapidity, and passes to the state of oxy-

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* Trommsdorf, *Ann. de Chim.* xi. 314.

† Wenzell's *Verwand.* p. 331.

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prussiat. Oxy-muriatic and nitric acids produce the same change.

2. *Oxy-prussiat of iron.* This salt is formed when triple prussiat of potass is poured into oxy-sulphat of iron, or into the solution of any oxygenated salt of iron. A beautiful blue precipitate appears, which is the salt. It is not altered by the acids. Sulphurated hydrogen gas converts it into prussiat by absorbing oxygen. When it is mixed with iron-filings, and kept in water in a close vessel, it is also converted into prussiat, the iron absorbing the second dose of oxygen from the red oxide *.

Sp. 22. *Sebat of Iron.*

SEBACIC ACID dissolves iron, and forms with its oxide deliquescent needle-shaped crystals. It does not precipitate the solutions of iron in sulphuric and nitric acids †.

GENUS VII. 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 these salts 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.

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* Proust, *Ann. de Chim.* xxii. 88.

† Crell, *Phil. Trans.* 1782.

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 which contain the metal oxidated to a minimum are extremely ready to absorb oxygen, and to pass into the state of oxygenated 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.

2. Triple prussiat of potass occasions a white precipitate when dropt into these solutions.

3. Hydrosulphuret of potass occasions a black precipitate; sulphurated hydrogen gas, a brown precipitate.

4. Neither gallic acid nor the infusion of nutgalls occasions any precipitate.

5. 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.

6. When muriat 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.

Sp. 1. *Sulphat of Tin.*

Sulphuric acid is capable of dissolving tin; but the properties of the compounds which it forms 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, attempt-

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ed 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 oxidated to a maximum, and the *oxy-sulphat* 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 it, in either of these cases a *sulphat* of tin is formed, which yields, when evaporated, crystals in the form of fine needles, as was observed long ago by Monnet.

[Sp. 2. *Sulphite of Tin.*

THE action of sulphurous acid upon tin has been examined lately 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 oxidated, 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 sulphite of tin combined with a portion of sulphur; for sulphur precipitates when sulphuric acid is added to the solution*.

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* Fourcroy, vi. 30.

Sp. 3. *Nitrated Tin.*

Action of nitric acid on 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.

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 *nitrat* of tin. It becomes gradually opaque, and deposites a white powder, which is an oxide of tin with a minimum of oxygen, as Proust has demonstrated. This oxide separates in greater abundance if the solution be heated. During the solution of the tin a quantity of ammonia is formed, as Morveau first observed. When potass is dropt 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 azot of the other, formed ammonia. If a little nitric acid be poured in, and heat applied, the tin precipitates oxidated to a maximum *.

When nitric acid, of the specific gravity 1.25, is poured upon tin, a very violent action takes place, the metal is oxidated to a maximum, and the whole of it separates from the liquid. Hence we see that there is no *oxy-nitrat* of tin; that metal, when combined with a maximum of oxygen, not being susceptible of entering into combination with nitric acid. When the liquid is evaporated, nitrat of ammonia is obtained. Morveau found, that 1 part of strong nitric acid and $1\frac{1}{2}$ 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 $\frac{1}{20}$ 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 azot combine, and form ammonia, while the whole of their oxygen unites with the tin.

Sp. 4. *Muriated Tin.*

Muriatic acid dissolves tin in considerable quantity when its action is assisted by heat. The water of the acid is decomposed, its oxygen combines with the tin, while the hydrogen is emitted in the form of gas. This gas has usually a fetid smell, owing, according to Mr Proust, to a quantity of arsenic which it holds in solution, and which is partly deposited on the sides of the jars in which the gas is kept. During the solution of the tin, the arsenic which it usually contains is precipi-

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* Proust, *Jour. de Phys.* li. 173.

† *Encyc. Method. Chim.* i. 632.

tated in the metallic state in the form of a black powder; so that the quantity of arsenic contained in tin may be ascertained by dissolving it in muriatic acid, provided that portion which is carried off by the hydrogen gas be also taken into account*. Muriatic acid combines with both the oxides of tin, and forms with them permanent salts.

1. *Muriat of tin.* This is the salt obtained by dissolving tin in about four times its weight of muriatic acid. The solution has a brownish-yellow colour, and yields when evaporated small needle-shaped crystals, soluble in water, and somewhat deliquescent. Their specific gravity is 2.2932 †.

Affinity for oxygen.

This salt has a strong affinity for oxygen, and absorbs it with avidity from the air, from oxy-muriatic acid, and from nitric acid, and is converted into oxymuriat of tin, as Pelletier first observed. It absorbs oxygen also from arsenic acid, and the white oxide of arsenic. When these bodies are treated with muriat 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 dropt into a solution of muriat 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 oxygenated salts of iron and copper are also reduced to salts with a minimum of oxygen, and the

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* Proust, *Jour. de Phys.* li. 175.

† Hassenfratz, *Ann. de Chim.* xxviii. 12.

muriat 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 muriat *.

2. *Oxy-muriat of tin.* This salt may be formed very conveniently by the process first proposed by Pelletier, which consists in causing oxy-muriatic acid gas to pass into a solution of muriat of tin till it be saturated, and then to expel the excess of acid by heat. But it was known long before this process was thought of, and was usually distinguished by the name of *smoking liquor of Libavius;* because Libavius, a chemist of the 16th century, was the discoverer of it. When equal parts of amalgam of tin † and oxy-muriat of mercury are triturated together, and then distilled in a retort with a very moderate heat, there passes first a colourless liquid, consisting chiefly of water, and afterwards a white vapour rushes all of a sudden into the receiver. This vapour condenses into a transparent liquid, which exhales a heavy dense smoke when exposed to the air, but does not smoke when confined in close vessels. This is the fuming liquor of Libavius, or oxy-muriat of tin.

Preparation.

The theory of the process is obvious: The tin abstracts oxygen from the mercury, and at the same time combines with the muriatic acid. Muriats of mercury and of tin are also formed, and line the neck of the retort mixed with a quantity of pure mercury; and there

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* Pelletier, *Ann. de Chim.* xii. 225.—Proust, *Jour. de Phys.* li. 173.

† Composed of two parts of tin and one of mercury.

remains behind an amalgam of tin, covered with a crust of muriat of tin[*]. It had been long known that this liquid contained muriatic acid and tin; but Adet was the first who demonstrated that the tin was oxidated to a maximum, and that therefore the salt was an oxy-muriat of that metal[†]; and his conclusions were afterwards confirmed by Pelletier[‡].

The white smoke constantly exhaled by this salt, prepared according to the process of Libavius, has also been accounted for by Adet. The salt is nearly destitute of water, and in this state it is exceedingly volatile. The vapour as it rises combines with the vapour of the atmosphere, and the smoke appears at the moment of the combination. When the salt is confined in a glass jar, either in moistened air or standing over water, it condenses gradually on the sides of the jar in the form of small crystals, having imbibed the water necessary for its crystallization from the air. When thrown into water, this substance produces heat, and at the same time dissolves if the quantity of water be sufficient. Adet ascertained, that when 7 parts of water are mixed with 22 parts of fuming muriat, the mixture condenses into a solid mass. This mass melts like ice when exposed to heat, and condenses again when cooled and agitated.

Oxy-muriat of tin is capable of dissolving an additional dose of tin without effervescence or the exhalation of gas, and by that means is converted into muriat of tin. The new portion of tin in this case deprives the tin of the oxy-muriat of its second dose of oxygen. Adet, however, found, that this solution did not suc-

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[*] Rouelle.

[†] *Ann. de Chim.* i. 5.

[‡] Ibid. xii 225.

ceed except in the oxy-muriat, rendered solid by mixture with water, and then liquefied by heat *.

Liquid oxy-muriat of tin yields by evaporation small crystals; and when heated sublimes in the same manner as fuming muriat. This salt is employed by dyers in great quantities, as it forms the basis of the scarlet dye. They usually prepare it by dissolving tin in nitro-muriatic acid; the consequence of which is, that the nature of the solution varies according to the proportion of the acids and the manner of dissolving the tin. In some cases, it is merely a muriat; in others, an oxy-muriat; and, generally, it consists of a mixture of the two. Hence the difficulty of which dyers complain of forming with this solution the same shade of colour in different circumstances. This would be in a great measure removed by preparing the salt according to the process recommended by Pelletier.

Sp. 5. *Phosphat 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 phosphat †. This salt precipitates also when the alkaline phosphats are mixed with a solution of muriat of tin: but its properties have never been examined.

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* *Ann. de Chim.* i. 16.

† Pelletier, *Ann. de Chim.* xiii. 16.

Sp. 6. *Fluat of Tin.*

Fluoric acid does not attack tin; but it dissolves its oxide, and forms with it a gelatinous solution, which has a strong disagreeable taste *. This fluat may be formed also by mixing together an alkaline fluat and the muriat of tin.

Sp. 7. *Borat of Tin.*

Boracic acid does not attack tin: but according to Palm, equal parts of tin-filings and boracic acid, melted together and dissolved in water, yield by evaporation transparent white polygonous crystals.

Sp. 8. *Carbonat 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 combine carbonic acid with the oxides of tin †; and when precipitated from their solution in acids by alkaline carbonats, he found that their weight received scarcely a perceptible increase ‡. Nor have the attempts of Proust to combine it with carbonic acid been attended with more success §.

Sp. 9. *Arseniat of Tin.*

When tin is treated with arsenic acid in a digesting heat, it is slowly oxidated at the expence of the acid, and the solution at last assumes the form of a gelatinous mass. Arsenic acid precipitates tin from acetous acid, and the alkaline arseniats occasion a precipitate

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* Scheele, i. 34.

† *Opusc.* i. 37.

‡ Ibid. ii. 392.

§ *Jour. de Phys.* li. 167.

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when poured into muriat of tin. The precipitate is arseniat of tin in the form of an insoluble powder, which hitherto has not been examined *.

Sp. 10. *Acetite of Tin.*

Action of vinegar on tin vessels.

ACETOUS ACID attacks tin very slowly, even when assisted by heat, and oxidates 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 his 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 of the vessel only which was in contact both with the vinegar and the air †.

When acetous acid is boiled upon tin, the metal is gradually dissolved, combining with oxygen at the expence 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 acetite of tin

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* Scheele, i. 180.

† *Ann. de Chim.* xxxii. 243.

by spontaneous evaporation *. It is easy to account for the different results obtained by these chemists. The crystals were no doubt *acetite* of tin, the gummy mass *oxacetite* of tin.

Sp. 11. *Oxalat 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. 12. *Tartrite of Tin.*

THE tartrite of tin has never been examined by chemists. The acid does not attack the metal, but it dissolves the oxid of tin.

Sp. 13. *Tartrite of Potass-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 carbonats ‡.

Sp. 14. *Benzoat of Tin.*

NEITHER tin nor its oxide is soluble in benzoic acid; but when benzoat of potass is poured into a solution of tin in nitro-muriatic acid, benzoat of tin precipitates. It is soluble in water by the assistance of

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* *Encycl. Method. Chim.* i. 23.

† Bergman i. 269.

‡ Thenart, *Ann. de Chim.* xxxviii. 35.

heat, but insoluble in alcohol, and decomposed by the action of heat *.

Sp. 15. *Succinat of Tin.*

SUCCINIC ACID dissolves the oxide of tin when assisted by heat. The solution by evaporation yields thin, broad, transparent crystals †.

Sp. 16. *Sebat of Tin.*

TIN, by the action of sebacic acid, is corroded into a yellow powder, especially if heat be applied. The solution is turbid, and deposites gradually a yellow powder, acquiring at the same time a fine red colour. When the yellow powder is dissolved in water, a white deliquescent salt is obtained ‡.

GENUS VIII. SALTS OF LEAD.

THOUGH lead be one of the most abundant and useful metals, though it has been known from the earliest ages, and though it is without difficulty dissolved by the greater number of acids, its salts have not hitherto been much examined by chemists. This is to be regretted; because the various degrees of oxidation of which it is susceptible, afford an excellent opportunity of ascertaining how many different salts it is capable of forming with each peculiar acid; and this once known, would probably lead to some general conclusions concerning the different classes of metallic salts. The salts of lead were formerly distinguished by the name of *saturn*, the

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* Trommsdorf, *Ann. de Chim.* xi. 315.

† Wenzel's *Verwand*, p. 337.

‡ Crell, *Phil. Trans.* 1782.

title by which lead was known among the alchymists. They 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. Triple prussiat of potass occasions a white precipitate when poured into solutions containing salts of lead.

5. Hydro-sulphuret of potass occasions a black precipitate. The same precipitate is produced by sulphurated hydrogen.

6. Gallic acid and the infusion of nutgalls 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.

Though lead is susceptible of combining with several doses of oxygen, it does not appear that each of its oxides is capable of combining with acids. As far as is known at present, it is only the oxides containing a minimum and maximum of oxygen that possess that property. None of the attempts to combine the red oxide of lead with acids have been attended with success. The white oxide combines with all acids hitherto tried; only the salts formed by means of that oxide have been hitherto examined: the combinations of the brown oxide have been almost completely overlooked. At present, therefore, we are acquainted with but few oxygenated salts of lead.

Sp. 1. *Sulphat 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 sulphat of lead. It may be obtained readily by pouring sulphuric acid into acetite of lead, or by mixing this last salt with any of the alkaline sulphats. The sulphat of lead precipitates in the state of a white powder. This salt has but little taste. Its specific gravity is 1.8742[*]. According to Kirwan, it requires 1200 parts of water to dissolve 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 is found native crystallized, according to Kirwan, in four-sided oblique angled prisms[‡], according to Hauy, in regular octahedrons[§]. It is insoluble in alcohol and in acetous acid.

Composition.

According to the experiments of Kirwan, it is composed of . . . . 23.37 acid

75.00 white oxide

1.63 water

100.00

And 100 parts of it contain exactly 71 parts of lead in the metallic state[**].

In close vessels this salt endures a considerable heat

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[*] Hassenfratz, *Ann. de Chim.* xxviii. 12.

[†] *Mineralogy*, ii. 211.

[‡] Kirwan's *Min.* ii. 211.

[§] *Jour. de Min.* An. v. p. 508.

[**] Kirwan *on Mineral Waters*, Table iv.

without alteration; but on charcoal it melts, and the lead is quickly reduced. This salt is sometimes employed as a paint instead of *white lead* or the white oxide of lead.

Sp. 2. *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 white oxide of lead, and forms with it a sulphite, which is in the state of a white powder, insoluble in water, and tasteless. Before the blow-pipe, on charcoal, it melts, becomes yellow, and the lead is at last reduced. When heated in close vessels, it gives out water, sulphurous acid, and sulphur, and is converted into sulphat of lead [*].

Sp. 3. *Nitrat of Lead.*

NITRIC ACID dissolves lead readily when not too much concentrated. The effervescence which accompanies the solution is occasioned by the emission of nitrous gas. The white 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 white oxide of lead only which combines with nitric acid. Six-sevenths of the red oxide are decomposed; their excess of oxygen combines with the remaining seventh, and converts it into brown oxygen, while their base of white oxide combines with the acid.

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[*] Fourcroy and Vauquelin, *Connaissances Chimiques*, vi. 86.

[†] Proust.

The solution of lead in nitric acid yields by evaporation transparent crystals, in the form of tetrahedrons truncated near their base, and likewise of six-sided truncated pyramids, having their faces alternately large and small*. These crystals have a sweet and at the same time an acrid taste. Their specific gravity is 4.068†. They are very soluble in water, like all the nitrats. When heated they decrepitate, and then undergo a kind of detonation, emitting very brilliant sparks‡. When they are trituated with sulphur in a hot mortar, a feeble detonation is produced, and the lead is reduced to the metallic state§.

This salt is decomposed by the alkalies, which combine with its acid, while the white oxide of lead is precipitated. Sulphuric, sulphurous, and muriatic acids combine with its base, and the new formed salt precipitates in the state of a white powder.

Sp. 4. *Muriated Lead.*

Muriatic acid attacks lead when assisted by heat, and oxidates and dissolves a portion of it; but its action is feeble and limited. It combines readily with the white oxide of lead. When poured upon the red oxide, it is converted partly into oxy-muriatic acid by the assistance of heat, while the lead, reduced to the state of white oxide, combines with the remainder of the acid‖. Thus we see that muriatic acid combines usually with white oxide of lead, and that it is incapable of combining with the red oxide of that metal; but the

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* Rouelle.

† Hassenfratz, *Ann. de Chim.* xxviii. 12.

‡ Bergman, ii. 470.

§ Van Mons, *Ann. de Chim.* xxvii. 81.

‖ Fabroni.

experiments of Proust and Vauquelin have proved that it is capable of combining also with the brown oxide, and forming an oxy-muriat of lead.

1. *Muriat of lead.* This salt may be formed readily by pouring muriatic acid or an alkaline muriat into a solution of nitrat of lead. The muriat 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 acetous acid; a property by which it may be readily distinguished from sulphat 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 brilliant appearance like satin. These crystals are not altered by exposure to the air. When heated they melt readily, and when cold assume the appearance of a semitransparent, greyish-white mass, formerly distinguished by the name of *plumbum corneum.* When exposed to a strong heat, they partly evaporate in a visible white smoke, and there remains behind a submuriat of lead; a substance which seems to have been first examined by Bergman‡.

Composition.

This salt, according to Klaproth, is composed of about . . . . 13.5 acid
86.5 oxide

100.0§

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* Hassenfratz, *Ann. de Chim.* xxviii. 12.

† Chenevix, Nicholson's *Jour.* iv. 223.

‡ Bergman, ii. 470. and iii. 325.

§ Beitrage, ii. 275.

According to Kirwan, the crystals are composed of

18.23	acid
81.77	oxide
100.00	

And the salt, when dried, of

17	acid
83	oxide
100*	

According to this calculation, we may consider 100 parts of the crystallized salt as containing 76 parts of lead in the metallic state.

Formation.

2. *Oxy-muriat of lead.* When the red oxide of lead is put into a Woulfe's bottle with water, and oxy-muriatic acid gas is made to pass through it, the gas is absorbed, while the oxide acquires a brown colour, and is gradually dissolved. For this curious experiment we are indebted to Mr Proust. In this case the lead absorbs oxygen from the acid, and from a portion of the red oxide also, which is converted into white oxide, and combines with the muriatic acid as it is developed; while the brown oxide, thus formed, combines with new oxy-muriatic acid, and is thus dissolved. The properties of this super-oxygenated salt have not been examined. It is not even known whether it can be crystallized. Its crystals, if they could be formed, would certainly be curious, as they would contain a much greater proportion of oxygen than any other metallic salt whatever. The solution does not crystallize spontaneously; and when evaporated, the acid is apt to fly off, and the brown oxide to be precipitated.

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* Kirwan *On Mineral Waters*, Table iv.

Sp. 5. Phosphat of Lead.

Phosphoric acid has but little action on lead; however, when allowed to remain long in contact with it, the metal is partly oxidated and converted into an insoluble phosphat. The phosphat of lead may be easily formed by mixing the alkaline phosphats with nitrat of lead. The salt immediately precipitates in the state of an insoluble powder.

The salt is found native in different parts of the world. Its colour is then usually green or yellow, and it is often crystallized in six-sided prisms. It 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 *. 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 sulphuric, nitric, and muriatic acids, decompose it by abstracting its base while cold; but these decompositions do not take place in a strong heat.

The yellow phosphat of lead, from Leadhills in Scotland, is composed, according to my analysis (abstracting the impurities with which it is usually mixed) of.

Composition.

18 acid
82 white oxide

100

Sp. 6. Fluat of Lead.

Fluoric acid has no action on lead; but it dissolves

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* Vauquelin, *Jour. de Min.* No. 9. p. 6.

a small proportion of the white oxide of that metal when there is an excess of acid. But the fluat of lead, formed by saturating the acid, is an insoluble powder, which melts easily before the blow-pipe, and lets go its acid. The acid is driven off also by sulphuric acid *.

Sp. 7. *Borat of Lead.*

Boracic acid has no action on lead; but borat of lead is precipitated in the state of white powder when borat of soda is mixed with nitrat of lead. 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 †.

Sp. 8. *Carbonat of Lead.*

Carbonic acid has no action on lead; but it combines readily with its oxide. Carbonat of lead is most easily obtained by precipitating lead from its solution in nitric acid by the alkaline carbonats. By that process it is obtained in the state of a white powder.

This salt occurs native in abundance. 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, and sometimes in regular octahedrons §. 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.

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* Scheele, i. 33.

† Reuss *de Sale Sedativo.*

‡ Bournon, Nicholson's *Journal*, iv. 220.

§ Hauy, *Jour. de. Min.* An. v. p. 502.

Composition.

Carbonat of lead, according to the experiments of Bergman, is composed of 16 acid
84 white oxide
100 *

This result nearly coincides with the experiments of Chenevix, who found carbonat of lead to be composed of . . . . 15 acid
85 oxide
100 †

According to Bergman, 132 parts of carbonat of lead contain 100 parts of metallic lead.

Sp. 9. *Arseniat of Lead.*

ARSENIC ACID attacks lead in a digesting heat, communicates a portion of its oxygen, and converts it into arseniat of lead in the state of an insoluble white powder. When arsenic acid is poured into the solution of lead in nitric, muriatic, or acetous acids, arseniat 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.

Composition.

Arseniat of lead is completely insoluble in water. It has been found native. According to the analysis of Chenevix, it is composed of 33 acid
63 white oxide
4 water
100 ‡

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* Bergman, ii. 393.

† Nicholson's *Journal*, iv. 221.

‡ *Phil. Trans.* 1801, p. 199.

Sp. 10. *Molybdat of Lead.*

The action of molybdic acid on lead has not been tried; but Scheele ascertained, that when dropt into the solution of lead in nitric or muriatic acid, molybdat of lead was immediately precipitated*. 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‡

Sp. 11. *Chromat of Lead.*

This salt may be formed by mixing together the solutions of nitrat of lead and an alkaline chromat. The chromat of lead, in that case, precipitates in the state of a red 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.

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* Scheele, i. 246.

† Hatchett, *Phil. Trans.* 1796.

‡ Beitrage, ii. 275.

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 muriat or sulphat. According to the analysis of Vauquelin, it is composed of

about	34.9 acid
	65.1 oxide
	100.0*

Sp. 12. *Acetite of Lead*

Acetous acid, as Vauquelin has shewn, does not attack lead in close vessels; but it occasions its oxidation when the lead is in contact both with the acid and the air, and the oxide is dissolved as it forms. The acetite of lead which is produced by this solution 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*, *vinegar of Saturn*, *extract of Saturn*, &c. The solution of lead in acetous acid was strenuously recommended by Goulard, a surgeon of Montpelier, as an excellent application in cases of inflammation. Hence it is often called *Goulard's extract.*

Formation.

This salt is employed in considerable quantities by dyers and calico printers. They mix it with alum or with sulphat of iron, and by that means compose acetite 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

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* *Jour. de Min.* No. xxxiv. p. 760.

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 Machy, and more lately by Pontier *.

These processes may be reduced to two; either lead in the metallic state is exposed to the action of the acetous acid, or the oxides of lead are dissolved in it. In the first case, thin plates of lead are put into earthen vessels along with acetous 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 acetite of lead precipitates in small crystals.

Other manufacturers dissolve the white oxide of lead, prepared by exposing the metal to the fumes of vinegar; or they 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 carbonat of lead, which is found abundantly in many places, be employed with advantage instead of these artificial oxides?

Properties.

Acetite of lead is usually in the form of small needle-shaped crystals, which have a glossy appearance like satin, and are flat four-sided prisms, terminated by dihedral summits. Its taste is sweet and somewhat astrin-

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* *Ann. de Chim.* xxxvii. 268.

gent. Its specific gravity is 2.345 *. It is but sparingly soluble in water, unless there be an excess of acid. When exposed to the air it becomes yellow, but undergoes no farther change. Heat decomposes it. When distilled, there comes over an acid liquor, which is the acetous considerably altered; and the residuum, according to Proust, often takes fire spontaneously when exposed to the air. 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.

Sp. 13. *Oxalat of Lead.*

Oxalic acid blackens lead, but it is scarcely capable of dissolving it; but it dissolves its white oxide, and when nearly saturated deposites small crystalline grains of oxalat of lead. The same crystals are precipitated when oxalic acid is dropt into the nitrat, muriat, or acetite of lead dissolved in water. They are insoluble in alcohol, and scarcely soluble in water, unless they contain an excess of acid. They are composed, according to Bergman's analysis, of about

41.2 acid
58.8 oxide

100.0 †

Sp. 14. *Tartrite of Lead.*

Tartarous acid has no action on lead; but it combines with its oxide, and precipitates tartrite of lead in the state of an insoluble white powder, from the nitrat,

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* Hassenfratz, *Ann. de Chim.* xxviii. 12.

† Bergman, i. 267.

muriat, and acetite of that metal. According to the analysis of Thenart, it is composed of

34	acid
66	white oxide
100 [*].	

Sp. 15. *Tartrite of Potass-and-lead.*

This triple salt may be formed by boiling tartar and oxide of lead together in water. Thenart informs us that it is insoluble, and that it is neither decomposed by alkalies nor by sulphats [†].

Sp. 16. *Malat of Lead.*

Malic acid does not attack lead; but when poured into a solution of lead in nitric or acetous acid, malat of lead is immediately precipitated [‡]; and likewise, as Vauquelin has observed, when acetite of lead is poured into a solution containing malat 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 acetous and weak nitric acids [§].

Sp. 17. *Lactat of Lead.*

Lactic acid, when digested upon lead for several days, dissolves it. The solution has a sweet and astringent taste, and does not crystallize [||].

Sp. 18. *Mucite of Lead.*

When mucous acid is dropt into the solution of lead

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[*] *Ann. de Chim.* xxxviii. 37.

[†] Ibid. p. 36.

[‡] Scheele, Crell's *Annals*, ii. 7. Engl. Transl.

[§] *Ann. de Chim.* xxxv. 155.

[||] Scheele, ii. 66.

in muriatic or nitric acids, a white insoluble precipitate is produced [*].

Sp. 19. *Benzoat of Lead.*

Benzoic acid dissolves lead with difficulty. The solution yields by evaporation crystals of benzoat 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 [†].

Sp. 20. *Succinat of Lead.*

Succinic acid scarcely attacks lead, but it dissolves its white oxide; and the solution, according to Wenzel, yields long slender foliated crystals [‡].

Sp. 21. *Sebat of Lead.*

Sebacic acid oxidates lead, and dissolves a good deal of its oxide. It precipitates lead from its solution in nitric and acetous acids in the form of white needle-shaped crystals, soluble in water and in acetous acid [§].

Genus IX. 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 accurate examination of the combinations which its oxide forms with acids. The salts of nickel, therefore, are at present but very imperfectly

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[*] Scheele, ii. 80.

[†] Trommsdorf, *Ann. de Chim.* xi. 316.

[‡] Wenzel's *Verwand*, p. 322.

[§] Crell, *Phil. Trans.* 1782.

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. Triple prussiat of potass, when dropt into these solutions, occasions a precipitate of a dull green colour.

3. The hydrosulphuret of potass occasions a black precipitate.

4. Sulphurated hydrogen gas, according to Proust, occasions no precipitate.

5. Gallic acid, and the infusion of nutgalls, occasion a greyish white precipitate.

6. Iron, zinc, tin, manganese, or cobalt, when plunged into these solutions, occasion a precipitate of nickel in the metallic state.

Sp. 1. *Sulphat of Nickel.*

Sulphuric acid attacks nickel by the assistance of heat. When distilled over it to dryness, there remains behind a green mass soluble in water, and yielding by evaporation crystals of sulphat of nickel. This acid dissolves the oxide of nickel with facility, and yields by evaporation the same salt. The sulphat of nickel has a fine green colour, and crystallizes in decahedrons composed of two four-sided pyramids applied base to base, and truncated at their apexes*. Fourcroy informs us that he has seen this salt, prepared by Leblanc, crystallized in large four-sided rectangular prisms.

Sp. 2. *Nitrat of Nickel.*

Nitric acid dissolves nickel or its oxide when as-

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* Bergman, ii. 268.

sisted by heat. The solution has a bluish-green colour, and yields by evaporation nitrat 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[*].

Sp. 3. *Muriat of Nickel.*

MURIATIC ACID dissolves nickel and its oxide slowly, and the assistance of heat is necessary. The solution, which has a green colour, yields when evaporated irregular crystals of muriat of nickel, which are decomposed by heat and by long exposure to the air, though at first they deliquesce like nitrat of nickel[†].

Sp. 4. *Phosphat 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 phosphat of nickel is nearly insoluble.

Sp. 5. *Fluat of Nickel.*

FLUORIC ACID dissolves nickel with difficulty, and the solution yields light green-coloured crystals[§].

Sp. 6. *and* 7. *Borat and Carbonat.*

BORACIC ACID can only be combined with nickel by mixing an alkaline borat with a solution of nickel in some acid.

It does not appear from the experiments of Berg-

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[*] Bergman, ii. 268.

[†] Ibid.

[‡] Ibid.

[§] Ibid.

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man that carbonic acid is capable of combining with nickel directly; but when 100 parts of nickel are thrown down from their solution in acids by an alkaline carbonat, they weigh 135; whereas they weigh only 128 when thrown down by a pure alkali[*]. Hence we may conclude that the carbonat of nickel is composed of about . . . . . 95 oxide

5 acid

100

Sp. 8. *Arseniat of Nickel.*

When arsenic acid is digested on nickel, the metal is partly oxidated, and the arseniat of nickel separates in the form of a greenish powder scarcely soluble in water. Nickel is not precipitated from its solution in acids by arsenic acid; but when the alkaline arseniats are employed, arseniat of nickel falls in the state of a greenish-white powder[†].

Sp. 9. *Acetite of Nickel.*

Acetous acid dissolves nickel, and forms with its oxide rhomboidal crystals of a very green colour[‡].

Sp. 10. *Oxalat of Nickel.*

Oxalic acid attacks nickel at a digesting heat, and a greenish-white powder is deposited, which is the oxalat of that metal. The same salt is precipitated when oxalic acid is dropt into the solution of nickel in sulphuric, nitric, or muriatic acids. It is scarcely soluble

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[*] Bergman, ii. 392.

[†] Scheele, i. 187.

[‡] Bergman, ii. 268.

in water, and is composed, according to Bergman, of two parts of acid to one of metal[*].

Sp. 11. *Tartrite of Nickel.*

Tartarous 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 salts of nickel.

Genus X. 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 there is only one oxide of that metal, 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. Triple prussiat of potass occasions a white precipitate when dropt into these solutions.

3. Hydrosulphuret of potass and sulphurated hydrogen gas occasion a white precipitate.

4. Gallic acid and the infusion of nutgalls occasion no precipitate when dropt into these solutions.

5. Alkalies occasion a white precipitate, which is readily dissolved by sulphuric or muriatic acid.

6. It is not precipitated in the metallic form by any of the other metals, unless manganese be an exception.

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[*] Bergman, i. 269.

[†] Ibid.

Sp. 1. *Sulphat of Zinc.*

Concentrated sulphuric acid scarcely acts upon zinc without the assistance of heat; but if it be sufficiently diluted with water, it attacks 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 sulphat of zinc in crystals.

History.

This salt, according to the best accounts, was discovered at Rammelsberg in Germany about the middle of the 16th century. Many ascribe the invention to Julius Duke of Brunswick. Henkel and Newmann 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 sulphurated oxide of zinc, or blende as it is called by mineralogists. This ore is roasted, which converts the 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. 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-

Purification.

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* Beckmann's *History of Inventions*, art. *Zinc.*

filings; taking care to agitate it occasionally. The zinc precipitates all the iron, and takes its place. The solution is then to be filtered, and the sulphat of zinc may be obtained from it in crystals by proper evaporation.

Properties.

This salt when crystallized is transparent and colourless. Its crystals are four-sided flat prisms, terminated by quadrangular pyramids. Two opposite edges of the prism are commonly replaced by small faces, which renders the prism six-sided *. Its specific gravity when crystallized is 1.912, when in the state in which it commonly occurs in commerce, it is 1.3275 †.

At the temperature of 60°, it is soluble in 2.28 parts of water; but it is much more soluble in boiling water ‡. When exposed to the air, it effloresces. When heated, it melts and speedily loses its water of crystallization, and, in a very high temperature, loses part of its acid.

Composition.

According to the calculation of Bergman, this salt is composed of . . . . . 40 acid
20 oxide
40 water
100 §

According to Kirwan, it is composed of 20.5 acid
40.0 oxide
39.5 water
100.0 ||

According to the same philosopher, 100 parts of the crystallized salt contain 30 parts of metallic zinc.

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* Bergman, ii. 327.

† Hassenfratz, *Ann. de Chim.* xxviii. 12.

‡ Bergman ii. 328.

§ Ibid.

|| Kirwan's *Mineral Waters*, Table iv.

Sp. 2. *Sulphite of Zinc.*

HITHERTO the combinations which the sulphurous acid forms with metallic oxides have been examined only by Berthollet and Fourcroy and Vauquelin. To these chemists we are indebted for the discovery that the greater number of metallic sulphites are capable of combining with a quantity of sulphur, and of forming a *sulphurated sulphite*. This is the case in a remarkable degree with the sulphite of zinc.

Two varieties of sulphited zinc.

1. *Sulphurated sulphite.* Sulphurous acid attacks zinc with considerable violence, heat is produced, and sulphurated hydrogen gas is exhaled. The solution has an acrid, astringent, sulphureous taste. When exposed to the air, it becomes thick like honey, and deposites long slender crystals in the form of four-sided prisms, terminated by four-sided pyramids. These are crystals of *sulphurated sulphite 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 deposite a white insoluble powder. Before the blow-pipe 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 sulphat 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 were decomposed; the oxygen of both combined with the metal; the hydrogen escaped combined with a portion of the sulphur of the decomposed acid, and the rest of the sulphur combined with the sulphite as it formed.

2. *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 sulphurated sulphite. 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 sulphat of zinc; whereas the sulphurated sulphite remains long unchanged.

When a mixture of sulphur and white oxide of zinc is treated with sulphurous acid, the product is a sulphurated sulphite [*].

Sp. 3. *Nitrat of Zinc.*

NITRIC ACID attacks zinc with prodigious violence, and has been known 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 gas. The solution is 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. When 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 [‡].

Sp. 4. *Muriat of Zinc.*

MURIATIC ACID dissolves zinc rapidly and with

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[*] Fourcroy, v. 380.

[†] Hassenfratz, *Ann. de Chim.* xxviii. 12.

[‡] Fourcroy, v. 382.

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 muriat of zinc remains behind in a solid mass, easily fusible. It was formerly known by the name of *butter of zinc.* When heated, it sublimes, and is obtained in a mass of a fine white colour, composed of small needles. 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 whole oxide of zinc from its solution †.

Sp. 5. *Phosphat of Zinc.*

PHOSPHORIC ACID attacks zinc with effervescence, and a white powder is gradually deposited, which is the *phosphat of zinc.* The salt may be formed also by pouring an alkaline phosphat into the solutions of sulphat, nitrat, or muriat of zinc. Its properties have not been examined, but it appears to be nearly insoluble in water.

Sp. 6. *Fluat of Zinc.*

FLUORIC ACID attacks zinc with violence, hydrogen gas is emitted, and the metal is oxidated and dissolved. The properties of the fluat thus formed have not been examined ‡.

Sp. 7. *Borat of Zinc.*

BORACIC ACID scarcely attacks zinc; but it com-

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* Hassenfratz, *Ann. de Chim.* xxviii. 13.

† Fourcroy, v. 383.

‡ Scheele, i. 35.

bines with its oxide, and forms with it an insoluble *borat of zinc*. This salt may be precipitated by pouring borat of soda into the nitrat or muriat of zinc.

Sp. 8. *Carbonat 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 carbonat 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 carbonat. According to the analysis of Bergman, native carbonat of zinc is composed of

28 acid
66 oxide
6 water

100 [‡]

Sp. 9. *Arseniat 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 arseniat of zinc may be precipitated by

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[*] Bergman i. 35.

[†] *Opusc.* ii. 326.

pouring arsenic acid into the acetite of zinc, or by mixing the solution of the alkaline arseniats with the sulphat of zinc. It is a white powder, insoluble in water[*].

Sp. 10, 11, *and* 12.

By the same process may the tungstat, molybdat, and chromat of zinc be obtained. They also are insoluble in water: the first two are white, the last of an orange-red colour.

Sp. 13. *Acetite of Zinc.*

Acetous acid readily dissolves zinc, and yields by evaporation crystals of acetite 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 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[†].

Sp. 14. *Oxalat of Zinc.*

Oxalic acid attacks zinc with a violent effervescence, and a white powder soon subsides, which is oxalat of zinc. The same salt is precipitated when oxalic acid is dropt into the solution of sulphat, nitrat, or muriat of zinc. This salt is scarcely soluble in water, unless there be an excess of acid[‡].

Sp. 15. *Tartrite of Zinc.*

Tartarous acid attacks zinc with effervescence,

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[*] Scheele, i. 181.

[†] *Encycl. Method. Chim.* i. 23.

[‡] Bergm. i. 271.

and forms with it a salt difficultly soluble in water, the properties of which have not been examined *.

Sp. 16. *Tartrite of Potass-and-zinc.*

This salt may be formed by boiling together tartar and zinc filings in water. It is very soluble in water, and not easily crystallized. No precipitation is produced in its solution by the alkalies or their carbonats †.

Sp. 17. *Citrat of Zinc.*

Citric acid attacks zinc with effervescence, and gradually deposites small brilliant crystals of citrat of zinc. They are insoluble in water, and have a styptic and metallic taste. They are composed of

50 acid
50 oxide

100‡

Sp. 18. *Malat of Zinc.*

Malic acid dissolves zinc, and yields by evaporation beautiful crystals of malat of zinc §.

Sp. 19. *Lactat of Zinc.*

Lactic acid dissolves zinc with effervescence, and the salt formed is capable of crystallizing ||.

Sp. 20. *Benzoat of Zinc.*

Zinc is readily dissolved by benzoic acid. The so-

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* Dijon Academicians.

† Dijon Academicians; and Thenart, *Ann. de Chim.* xxxviii. 35.

‡ Vauquelin, *Fourcroy*, vii. 209.

§ Scheele, Crell's *Annals*, ii. 10. Engl. Transl.

|| Scheele, ii. 65.

lution yields crystals which are soluble in water and alcohol. When exposed to heat, their acid is volatilized *.

Sp. 21. *Succinat 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. 22. *Sebat of Zinc.*

SEBACIC ACID dissolves zinc with great facility; but the resulting salt has not been examined ‡.

GENUS XI. 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. Triple prussiat of potass occasions in these solutions a precipitate of a white colour, sometimes with a shade of yellow.

3. Hydrosulphuret of potass and sulphurated hydrogen gas occasion a black precipitate.

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* Trommsdorf, *Ann. de Chim.* xi. 317.

† Wenzel's *Verwand*, p. 330.

‡ Crell, *Phil. Trans.* 1782.

4. Gallic acid and the infusion of nutgalls occasion an orange-coloured 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.

Sp. 1. *Sulphat of Bismuth.*

SULPHURIC ACID has no action on bismuth while cold; but by the assistance of heat it converts that metal into a white oxide, 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, almost the whole of the acid is separated, carrying along with it 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.

Sp. 2. *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 sulphureous taste; and before the blowpipe melts into a reddish yellow mass, which is soon reduced upon charcoal. When distilled, the acid is driven off, and the whole oxide remains in a state of purity *.

Sp. 3. *Nitrat of Bismuth.*

NITRIC ACID, when concentrated, attacks bismuth

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* Fourcroy, v. 204.

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 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, generally terminated by four-sided summits.

Properties.

This salt, when exposed to the air, attracts a little moisture, and its surface is covered with a crust of white oxide. On burning coals it detonates feebly, emitting red sparks, and leaves a yellowish powder not easily reduced. When triturated with mercury it detonates loudly [*]. When put into water it is immediately decomposed; that liquid absorbing its acid and leaving the white oxide of bismuth. 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 white oxide. In this state it was formerly known by the name of *magistery of bismuth*, and in commerce it is distinguished by the appellation of *pearl white*. To obtain it of a fine white colour, it is necessary to employ a great proportion of water, and to wash the precipitate well.

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[*] Brugnatelli, *Ann. de Chim.* xxvii. 73.

[†] Ibid. iii. 296

Sp. 4. *Muriat of Bismuth.*

Muriatic acid has scarcely any action on bismuth while cold; but when distilled off that metal, previously reduced to powder, it gradually oxidates, and brings it to the state of a white powder. Muriat of bismuth may be readily formed by dissolving the metal in nitro-muriatic acid, or in oxy-muriatic acid. When the solution is evaporated, it is said to yield small prismatic crystals. The muriat of bismuth, when evaporated to dryness, sublimes by the application of a moderate heat, and forms a thick concrete mass, readily melting when heated, formerly known by the name of *butter of bismuth*. It was prepared also by distilling a mixture of two parts of oxy-muriat of mercury and one part of bismuth: an amalgam of bismuth remains in the retort, while the *butter*, as it was called, sublimes *.

Sp. 5, 6, 7, 8.

The combinations which the oxide of bismuth forms with phosphoric, fluoric, boracic, and carbonic acids, have not hitherto been examined with accuracy. They may be formed by pouring into the solution of bismuth in nitric acid the alkaline phosphats, fluats, borats, or carbonats. The salts required precipitate in the state of a white powder.

Sp. 9. *Arseniat of Bismuth.*

Arsenic acid oxidates bismuth by a digesting heat; and the metal is covered with a white powder, which is

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* Poli, *Mem. Par.* 1713.

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arseniat of bismuth. Part also of the arseniat remains in solution, but the oxide is precipitated by the addition of water. The arseniat of bismuth precipitates when arsenic acid is poured into the nitrat of bismuth. The white powder thus obtained is difficultly fusible; but when heated with charcoal, arsenic sublimes, and the bismuth is reduced *.

Sp. 10. *Acetite of Bismuth.*

Acetous acid has but little action on bismuth; but the acetite of bismuth may be obtained by mixing together the solutions of nitrat of bismuth and acetite of potass. 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 acetous acid deprives nitrat of bismuth of the property of affording a precipitate when diluted with water †.

Sp. 11. *Oxalat of Bismuth.*

Oxalic acid scarcely attacks bismuth; but it combines with its oxide, and forms with it an oxalat in the state of a white powder, scarcely soluble in water. When oxalic acid is dropt into nitrat of bismuth, small transparent polygonous grains are gradually precipitated, which possess the same properties as the white powder, and do not become opaque when put into water ‡.

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* Scheele, i. 184.

† *Encyc. Method. Chim.* i. 10.

‡ Bergman, i. 269.

Sp. 12. *Tartrite of Bismuth.*

Tartarous acid does not attack bismuth; but when dropt into the solution of that metal in nitrous acid, tartrite of bismuth precipitates in the state of a white powder insoluble in water.

Sp. 13. *Benzoat 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 *.

The remaining salts of bismuth are unknown.

Genus XII. Salts of Antimony.

The various doses of oxygen with which antimony is capable of combining, render it probable that the salts of antimony are numerous; but hitherto scarcely any of them have been examined. Chemists have confined themselves to the combination of the acidulous oxide of antimony with acids; an oxide which possesses a number of properties which assimilate it to the acids, and which seems scarcely susceptible of forming permanent compounds with acids. Antimonial salts may be distinguished by the following properties:

Characters.

1. Their solutions are usually colourless, and in most cases a white precipitate falls when they are diluted with water.

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* Trommsdorf, *Ann. de Chim.* xi. 317.

2. Triple prussiat of potass occasions a white precipitate when dropt into these solutions. This precipitate is merely the oxide of the metal precipitated by the water of the prussiat. When applied sufficiently concentrated, or in crystals, no precipitation takes place. In this property antimony agrees with platinum *.

3. Hydrosulphuret of potass occasions an orange-coloured precipitate.

4. Gallic acid and the infusion of nutgalls occasion a white 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.

Sp. 1. *Sulphat of Antimony.*

Sulphuric acid has no action on antimony while cold; but at the boiling temperature it oxidates that metal with effervescence, sulphurous acid is exhaled, and even sulphur sublimed, and there remains in the retort a soft white mass, evidently composed of the acidulous oxide and sulphurous acid. Water carries off the acid and a small portion of the oxide, but leaves the greater part in the state of a white powder. When the solution is evaporated, the remainder of the oxide precipitates, so that the salt cannot be obtained in a crystalline form. The white powder may be considered as a subsulphat of antimony, for it still retains a portion of acid.

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* Klaproth, Crell's *Annals*, 1798, i. 99.

Sp. 2. *Sulphite of Antimony.*

Sulphurous acid has no action on antimony while cold, but when hot it changes it into an oxide. The sulphite of antimony is precipitated in the state of an insoluble white powder when sulphurous acid is poured into the solution of antimony in muriatic acid. It has an acrid and astringent taste, melts when heated, and is volatilized and decomposed. When distilled in close vessels, it yields sulphurous acid; and there remains a reddish brown mass, consisting probably of hydrosulphuret of antimony *.

Sp. 3. *Nitrat of Antimony.*

Nitric acid attacks antimony with great violence. Both the acid and water are decomposed, abundance of nitrous gas is emitted, and a considerable portion of ammonia is formed and combines with the acid while the metal is converted into an insoluble white oxide. It does not appear that any combination takes place between this acid and the acidulous oxide of antimony, the oxide which is formed by this process; and no attempt has hitherto been made to combine it with any of the other oxides of antimony. Probably it does not combine even with them, in consequence of the facility with which it converts them into the acidulous oxide.

Sp. 4. *Muriat of Antimony.*

Muriatic acid has no effect upon antimony at first; but the metal is gradually dissolved when it is kept long in contact with that acid. The solution is

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* Fourcroy, v. 231.

yellow, and yields by evaporation small needle-form crystals, consisting no doubt of *muriat* of antimony, or of muriatic acid combined with antimony, oxidated to a minimum.

Muriatic acid dissolves the white oxide of antimony with facility; but it is nitro-muriatic acid which is considered as by far the best solvent of that metal. These solutions may be considered as containing an *oxy-muriat* of antimony, or muriatic acid combined with antimony oxidated to a maximum. That salt was formerly known by the name of *butter of antimony*. It was usually prepared by triturating together one part of antimony and two parts of oxy-muriat of mercury, and then distilling them in a retort. At a moderate temperature the oxy-muriat of antimony passes over. It is in the state of a thick fatty mass, of a greyish white colour, and often crystallized in four-sided prisms. It is exceedingly caustic, becomes coloured when exposed to the air, and melts at a very moderate temperature. When diluted with water, it is partly decomposed, and the greater part separates in the form of a white oxide. In this state it was formerly known by the name of *powder of Algoroth*.

Sp. 5. Phosphat of Antimony.

The action of phosphoric acid on antimony has never been examined. Neither is the salt better known which that acid may be supposed capable of forming with the oxides of that metal.

Sp. 6. Phosphat of Lime-and-antimony.

The well-known medicine called *James's powder* has been shewn by the analysis of Dr Pearson to be a compound of phosphoric acid, lime, and oxide of antimo-

ny; we may therefore consider it as a triple salt. It is usually in the form of a white powder, nearly insoluble in water, but partially soluble in acids. The energy with which it acts as an emetic is well known. From Dr Pearson's analysis it appears to be composed of about . . . . . 43 phosphat of lime
57 oxide of antimony
100

It may be composed by calcining in a white heat a mixture of equal parts of sulphuret of antimony and the ashes of bones *.

Sp. 7, 8, 9, 10, 11.

THE fluat, borat, carbonat, tungstat, and chromat of antimony are still unknown, no accurate experiments having been made to ascertain even the mode of forming these salts.

Sp. 12. *Arseniat of Antimony.*

WHEN arsenic acid and antimony are digested together, a white powder separates, consisting of arseniat of antimony. This powder is soluble in muriatic acid, and precipitated again by the affusion of water. The alkaline arseniats precipitate the same salt from the solution of antimony in muriatic, tartarous, or acetous acids. When a mixture of one part of antimony and three parts of arsenic acid are distilled in a retort, it enters into fusion, and then takes fire; arsenic is sublimed together with a red mass, and sulphurous acid is exhaled †.

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* *Phil. Trans.* 1791, p. 317.

† Scheele, i. 184.

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Sp. 13. *Acetite of Antimony.*

ACETOUS ACID has little or no action on antimony; but it dissolves a small portion of its oxide, as Morveau has shewn, 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. 14. *Oxalat 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 acetous or sulphuric acid; but oxalic acid occasions no precipitate in the oxy-muriat of antimony†.

Sp. 15. *Tartrite of Antimony.*

TARTAROUS 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‡.

Sp. 16. *Tartite of Potass-and-Antimony.*

History.

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,

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* *Encyc. Method. Chim.* i. 6. † Bergman, i. 371. ‡ Ibid. 370.

intitled *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.

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 numerous 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* †.

At present the glass of antimony, or the acidulous oxide 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.

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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.

Thenart has observed, that there always remains in the solution a quantity of uncombined tartrite of potass; 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 80 parts of cold water, and in about 40 parts of boiling water. Heat decomposes it by destroying the acid, while the potass and oxide of antimony remain behind. It is decomposed by the alkaline earths, by the alkalies and their carbonats, 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.

Composition.

From the analysis of Thenart, it appears that this salt is composed of . . . 35.4 tartarous acid
39.6 oxide
16.7 potass
8.3 water

100.0

Or of . . . . 56.3 tartrite of antimony
35.4 tartrite of potass
8.3 water

100.0 †

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* *Ann. de Chim.* xxxviii. 39.

† Ibid.

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Sp. 17. *Benzoat 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. 18. *Sebat of Antimony.*

SEBACIC ACID dissolves the oxide of antimony by the assistance of heat, and forms a salt in small crystals, which do not deliquesce in the air †.

GENUS XIII. SALTS OF TELLURIUM.

TELLURIUM has been known for so short a time as a distinct metal, and the quantity of it hitherto examined has been so small, that the salts which it forms with acids cannot be supposed to be much known. Only the following facts have been ascertained.

The salts of tellurium may be distinguished by the following properties:

Characters.

1. Alkalies, when dropt into their solution, occasion a white precipitate, which disappears again if the alkali be added in excess.

2. Triple prussiat of potass occasions no precipitate.

3. Hydrosulphuret of potass occasions a brown or blackish precipitate.

4. The infusion of nutgalls 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

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* Trommsdorf, *Ann. de Chim.* xi. 317.

† Crell, *Phil. Trans.* 1782.

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state of a black powder, which resumes its metallic brilliancy when rubbed *.

Sp. 1. *Sulphat 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 dropt 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. 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 †.

Sp. 2. *Nitrat of Tellurium.*

Nitric acid dissolves tellurium with facility. The solution is colourless, and yields, when concentrated, small white, light, needle-formed dendritical crystals ‡.

Sp. 3. *Muriat of Tellurium.*

Nitro-muriatic 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 precipite, soluble in muriatic acid §.

Genus XIV. Salts of Arsenic.

Arsenic is capable of assuming the form of an acid, and even its white oxide has several acid properties.

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* Klaproth, Crell's *Annals*, 1798, i. 98.

† Ibid. p. 98.

‡ Ibid. p. 97.

§ Ibid. p. 98.

Hence it is more disposed to combine with metallic bases than to form salts by uniting with acids. Indeed it has not been proved that the oxide of arsenic is capable of combining with acids, and of forming crystallizable salts. However, as several of the acids have the property of dissolving it, which must be considered as a species of combination, and as the knowledge of the properties of these solutions is sometimes of importance in mineralogical investigations, it will be proper to give an account of them in this place.

The solutions of arsenic may be distinguished by the following properties:

Characters.

1. Triple prussiat of potass occasions a white precipitate when poured into solutions containing arsenic *.

2. Hydrosulphuret of potass produces a yellow precipitate, or at least gives a yellow colour to the solution.

3. Gallic acid and the infusion of nutgalls occasion scarcely any change in the solutions of arsenic.

4. The addition of water occasions a white precipitate of oxide of arsenic †, which, when heated with charcoal, emits a white smoke, having the smell of arsenic.

Sp. 1. *Sulphat of Arsenic.*

Sulphuric acid has no action on arsenic while cold, but when heated, sulphurous acid gas is emitted, and the metal is converted into a white oxide, a small portion only of which is retained in solution. The acid

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* The solution of arsenic in those acids which convert it into an acid, is not disturbed by the triple prussiat of potass.

† Except when the arsenic is converted into an acid.

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dissolves equally a small quantity of the white oxide of arsenic; but the addition of water precipitates a white powder in the form of crystalline grains. These, according to Bergman, are composed of the white oxide of arsenic, combined with a small portion of acid *.

Sp. 2. *Nitrat of Arsenic.*

NITRIC ACID attacks arsenic with violence, and converts it into white oxide, while nitrous gas and azotic gas are emitted. An additional dose of acid converts the oxide into arsenic acid. There is therefore no such salt as nitrat of arsenic; the nitric acid does not combine with the white oxide.

Sp. 3. *Muriat of Arsenic.*

MURIATIC ACID has scarcely any action on arsenic while cold; but when heated it dissolves it readily, at the same time a quantity of arsenicated hydrogen gas is emitted. White oxide of arsenic is also dissolved by this acid with facility, especially if a little nitrous acid be mixed with it. At a boiling heat the muriatic acid dissolves about the third part of its weight of white oxide; but it allows the greater part to precipitate again as the solution cools. The addition of water precipitates the greatest part of the remainder; but the muriat of arsenic, according to the experiments of Bergman, may be obtained in the state of crystals. It is very volatile, and but sparingly soluble in water †.

This salt may be formed also by triturating together equal parts of oxy-muriat of mercury and oxide of arsenic, or metallic arsenic, and distilling the mixture

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* Bergman, ii. 292.

† Ibid. ii. 294.

with a moderate heat. There comes over a transparent liquor of the consistence of oil, part of which congeals in the receiver. This substance is muriat of arsenic. It was described by Lemery and others under the name of *butter of arsenic*, or *corrosive oil of arsenic.*

The action of the other acids on arsenic has scarcely been examined except by Bergman. According to him, phosphoric, fluoric, and arsenic acids dissolve it, and yield crystalline grains scarcely soluble in water: oxalic and tartarous acids dissolve the white oxide readily, and furnish prismatic crystals: acetous acid also dissolves it *.

GENUS XV. 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:

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* Bergman, ii. 295.

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Characters.

1. The greater number of them are soluble in water, and the solution has a reddish or brownish colour.

2. The alkalies, when dropt into these solutions, occasion a blue-coloured precipitate.

3. Triple prussiat of potass occasions a brownish yellow precipitate, often with a shade of blue.

4. Hydrosulphuret of potass occasions a black precipitate, soluble again if the hydrosulphuret be added in excess. According to Proust, sulphurated 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. Cobalt is not precipitated from its solution in acids by zinc.

Sp. 1. *Sulphat of Cobalt.*

Sulphuric acid oxidates cobalt with the assistance of heat; sulphurous acid gas is emitted, and there remains behind a brownish red mass readily dissolved by water. The solution is red; and yields by evaporation small needle-form crystals, consisting of rhomboidal prisms, terminated by dihedral summits. This salt has a reddish colour. When heated it melts, swells up, and is decomposed, leaving the oxide of cobalt of a deep blue colour. It is decomposed also by alkalies, which precipitate its base in the form of a flesh-coloured powder.

Sp. 2. *Nitrat of Cobalt.*

Nitric acid attacks cobalt with violence, especially when assisted by heat. The solution has a red colour,

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* *Ann. de Chim.* xxxv 54.

and yields by evaporation small prismatic crystals of a red colour, deliquescent in the air, and decomposed by heat, leaving a deep red powder.

Sp. 3. *Muriat of Cobalt.*

Muriatic acid acts with difficulty upon cobalt, even when assisted by heat; but it dissolves the oxide of that metal with great facility, and even takes it from sulphuric acid. The solution of oxide of cobalt in muriatic acid has a pale red colour, and yields by evaporation small deliquescent crystals of muriat of cobalt.

Sympathetic ink.

This solution 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 has shewn, 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. It takes place

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[*] Klaproth's *Observations on the Fossils of Cornwall*, p. 64. Eng. Trans.

[†] See Wiegleb's *Geschichte*, i. 126.

[‡] *Commerc. Litterarum*, p. 91.

[§] *Mem. Par.* 1737.

equally in close vessels; so that it can scarcely be ascribed to the action of the air or of moisture. At present it is supposed, but without any direct proof, to be owing to the partial deoxidation of the oxide of cobalt by heat, and its reabsorption of oxygen when cold.

Sp. 4, 5, 6, 7, 8, 9.

Phosphat. PHOSPHORIC ACID dissolves cobalt, and forms a reddish-coloured solution which deposites phosphat of cobalt when saturated.

Fluat. FLUORIC ACID does not attack cobalt, but it dissolves its oxide, and forms with it a yellow-coloured gelatinous solution *.

Borat. BORACIC ACID has no action on cobalt; but the borat of cobalt may be formed by mixing borat of soda with nitrat of cobalt.

Carbonat. CARBONAT OF COBALT may be formed also by precipitating cobalt from its solution in acids by means of an alkaline carbonat.

The *tungstat*, *molybdat*, and *chromat* of cobalt are still unknown.

Sp. 10. *Arseniat 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 arseniats occasion a precipitate of a fine red colour, which is arseniat of cobalt †. This salt is found native; sometimes in the state of a fine red efflorescence, and sometimes crystallized in small four-sided prisms or tables.

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* Scheele, i. 35.

† Ibid. 186.

Sp. 11. *Acetite of Cobalt.*

Acetous 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 *.

Sp. 12. *Oxalat of Cobalt.*

Oxalic acid attacks cobalt, and converts it into a red powder, which is oxalat of cobalt. This salt is insoluble in water, but it dissolves in an excess of acid, and yields crystals. Oxalic acid precipitates an oxalat of cobalt from the solution of that metal in most acids †.

The remaining salts of cobalt have not hitherto been examined.

Genus XVI. Salts of Manganese.

All 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 their instruments, was first put into the hands of chemists. 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.

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* Wenzel's *Verwand.* p. 194.

† Bergman, i. 270,

2. Triple prussiat of potass occasions a yellowish-white precipitate when dropt into these solutions.

3. Hydrosulphuret of potass occasions a white precipitate. Sulphurated hydrogen gas gives the solution a whiter colour, but produces no precipitate.

4. Gallic acid occasions no precipitate.

5. Manganese is not precipitated from its solution in the metallic state by any of the other metals.

Sp. 1. *Sulphated Manganese.*

Sulphuric acid acts with energy on manganese, especially when diluted with two or three times its weight of water, and forms with it a colourless solution. It dissolves also with equal facility the white and red oxides 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. Hence we see that the black oxide is incapable of combining with sulphuric acid, since it always loses a portion of its oxygen before solution. But Bergman has shewn, that both the white and the red oxide combine with that acid, and form with it a salt. So that we have two combinations of sulphuric acid and manganese: first, the combination of sulphuric acid and the white oxide, which form *sulphat* of manganese; and, secondly, the combination of the acid with the red oxide, which constitutes *oxy-sulphat* of manganese.

1. *Sulphat of manganese.* This salt is obtained pure by dissolving manganese in diluted sulphuric acid, or by dissolving the black oxide in that acid, adding at the same time a little sugar. The solution is colour-

less, and yields by evaporation transparent rhomboidal crystals of sulphat of manganese. These crystals have a very bitter taste, and are decomposed by heat, which drives off their acid. Alkalies precipitate from them the manganese in the state of a white oxide*.

2. *Oxy-sulphat 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 liquid is thus obtained, which holds in solution the oxy-sulphat 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 sulphat 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.

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* Bergman, ii. 210.

† Ibid. p. 215.

‡ Scheele, i. 43.

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Sp. 2. *Nitrated Manganese.*

Nitric acid dissolves manganese with effervescence, occasioned by the emission of nitrous gas. It dissolves the white oxide with facility, and without the emission of any gas: 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 white oxide. So that, as far as is known at present, there is no such substance as *oxy-nitrat* of manganese. This solution does not crystallize how slowly so ever it be evaporated. Heat decomposes it, and leaves the oxide *.

Sp. 3. *Muriated Manganese.*

Muriatic acid readily dissolves manganese with an effervescence occasioned by the emission of hydrogen gas. It dissolves the white oxide without effervescence, and the solution is colourless. When allowed to remain cold upon the black oxide, it dissolves a portion of it, and forms a red solution, which deposites red oxide when diluted with water. When heat is applied

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* Scheele, i. 43, 64; and Bergman, ii. 216.

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to the mixture of black oxide of manganese and muriatic acid, an effervescence takes place, and oxy-muriatic acid gas is emitted. The oxide becomes white and gradually dissolves. In this case the acid is divided into two portions; one absorbs oxygen from the metal, and flies off in the state of gas; the other dissolves the white oxide, as it is set at liberty by the decomposition of the black oxide. If sugar or any other similar vegetable substance is added, no oxy-muriatic acid gas is emitted, but instead of it carbonic acid gas. From these facts it is obvious that muriatic acid combines both with the white and red oxides of manganese; so that there is both a *muriat* and *oxy-muriat* of that metal. But the properties of these salts are still almost unknown. According to Bergman, the muriat crystallizes with difficulty, and when evaporated to dryness yields a saline mass, which attracts moisture. The solution of the oxy-muriat is red, and it seems to be partly decomposed by water [*].

Sp. 4. *Phosphat 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 phosphat of manganese may be obtained in the form of a precipitate, by mixing an alkaline phosphat with the solution of manganese in any of the three mineral acids [†]. This salt has not been hitherto examined.

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[*] Bergman, ii. 217.—Scheele, i. 46. and 67.

[†] Scheele, i. 48.—Bergman, ii. 219.

Sp. 5. *and* 6. *Fluat and Borat of Manganese.*

THE fluoric and boracic acids form likewise with the oxides of manganese salts difficultly soluble in water, the properties of which have not hitherto been much examined. These acids have but little action on manganese and its oxides; but the fluat or borat of manganese may be easily formed by pouring the alkaline fluats or borats into sulphat or muriat of manganese.

Sp. 7. *Carbonat of Manganese.*

LIQUID CARBONIC ACID attacks manganese or its black oxide, and dissolves a small portion. When the solution is exposed to the air, the acid gradually escapes, and a white pellicle forms on its surface, consisting of white oxide. During the solution of manganese in this acid, an odour similar to that of burning fat is perceptible *.

Remaining Species.

Acetite. 8. ACETOUS ACID has but little effect upon manganese immediately; but it dissolves a small portion by long digestion, as it does also of the black oxide. The solution does not yield crystals, and when evaporated to dryness soon deliquesces again †.

Oxalat. 9. Oxalic acid attacks manganese, and dissolves the black oxide with effervescence. The solution, when saturated, lets fall the oxalat 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 ‡.

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* Bergman, i. 35; and Scheele, i. 51

† Bergman, ii. 219.

‡ Ibid. i. 272, and ii. 219.

Tartrite.

10. Tartarous 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 acid and the escape of carbonic acid gas, and the solution becomes colourless. Tartrite of potass precipitates tartrite of manganese from the solution of that metal in any of the three mineral acids *.

Citrat.

11. Citric acid acts upon the black oxide of manganese exactly as tartarous acid †.

Arseniat.

12. Arsenic acid dissolves the white oxide of manganese with facility; and when it approaches the point of saturation, the solution becomes thick, with small crystals, which separate. These crystals are arseniat of manganese. They are precipitated when an alkaline arseniat is dropt 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 ‡.

Benzoat.

13. Benzoic acid dissolves the white oxide of arsenic with facility. The solution yields small crystalline scales easily soluble in water, but sparingly in alcohol. They are not altered by exposure to the air §.

GENUS XVII. SALTS OF TUNGSTEN.

THIS genus of salts is altogether unknown; the scarcity of tungsten, and the difficulty of obtaining it in a state of purity, having hitherto prevented the possibility of attempting to ascertain the compounds which its oxides are capable of forming with acids.

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* Bergman, ii. 219.

† Ibid. p. 220.

‡ Scheele, i. 188.

§ Trommsdorf, *Ann. de Chim.* xi. 317.

Neither sulphuric nor muriatic acids seem capable of altering the metal; but nitro-muriatic acid attacks it at a boiling heat, and nitrous gas is emitted *.

GENUS XVIII. SALTS OF MOLYBDENUM.

THIS genus is scarcely better known than the preceding, and for the same reasons. It has only been ascertained that muriatic acid does not attack molybdenum; that sulphuric acid oxidates it at a boiling heat; and that nitric acid converts it into molybdic acid.

GENUS XIX. SALTS OF URANIUM.

THIS genus of salts has been hitherto examined only by Klaproth and Richter. 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 carbonats a white precipitate, soluble in an excess of alkali.

3. Triple prussiat of potass occasions a brownish-red precipitate, which does not assume the form of flakes like the prussiat of copper.

4. Hydrosulphuret of potass occasions a brownish-yellow precipitate.

5. The infusion of nutgalls occasions a chocolate-coloured precipitate.

6. No precipitate is occasioned by zinc, iron, or tin †.

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* Vauquelin and Hecht, *Jour. de Min.* No. xix. p. 25.

† Klaproth, Crell's *Annals*, i. 130. Engl. Transl.

Sulphat.

Sp. 1. Sulphuric acid, when diluted, readily dissolves he yellow oxide of uranium, and the solution yields by vaporation fine orange-coloured prisms of sulphat of uranium [*].

Nitrat.

2. Nitric acid dissolves the oxide of uranium with acility, and the solution yields, when evaporated, arge crystals of nitrat of uranium of a beautiful yelowish-green colour, and in the form of hexagonal ables, which effloresce in the air [†].

Muriat.

3. Muriatic acid forms with oxide of uranium deliuescent crystals of a yellowish-green colour, and in the orm of four-sided tables [†].

Phosphat.

4. Phosphoric acid forms with oxide of uranium ellowish-white flakes, scarcely soluble in water. The alt may be precipitated by adding phosphoric acid to he acetite of uranium [‡].

Fluat.

5. Fluoric acid dissolves the yellow oxide, and forms ith it crystals which do not deliquesce.

Arseniat.

6. When an alkaline arseniat is dropt into nitrat of ranium, the arseniat of uranium precipitates in the tate of a yellowish-white powder.

7. and 8. The tungstat and molybdat of uranium ay be obtained by a similar process. The first is a rownish-white powder, insoluble in water; the second whitish-yellow, and difficultly soluble.

Acetite.

9. Concentrated acetous acid dissolves oxide of uraium by digestion, and yields beautiful yellow crystals n the form of long, slender, transparent, four-sided risms, terminated by four-sided pyramids. When eated gradually, the acid is decomposed and driven off,

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[*] Klaproth, Crell's *Annals*, i. 130. Engl. Trans

[†] Ibid.

[‡] Klaproth, ibid. p. 135.

but the remainingoxide still retains the form of the crystals *.

Tartrite.

10. Tartarous acid forms with the oxide of uranium a salt scarcely soluble in water.

Richter formed also the borat, oxalat, citrat, malat, benzoat, succinat, and sebat of uranium; but the properties of these salts have not been described.

GENUS XX. SALTS OF TITANIUM.

FOR all that is at present known respecting this genus of salts, we are indebted to the experiments o 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.

2. The alkaline carbonats occasion in these solution a white flaky precipitate.

3. Triple prussiat of potass occasions a grass-gree precipitate mixed with brown When an alkali is drop in after the prussiat, the precipitate becomes purple then blue, and at last white.

4. Hydrosulphuret of potass occasions a dirty glass green precipitate. Sulphurated hydrogen gas occasion no precipitate.

5. The infusion of nutgalls occasions a very bulk 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 o titanium, the liquid around it gradually assumes a fin

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* Klaproth, Crell's *Annals*, i. 135. Engl. Trans.

red colour. A rod of zinc, on the other hand, occasions a deep blue colour *.

Sulphat.

Sp. 1. Boiling sulphuric acid oxidates titanium, and dissolves a small portion of it; but on the red oxide of titanium that acid has no action whatever. It dissolves the carbonat of that metal with effervescence, occasioned by the emission of carbonic acid. The solution, when evaporated, is converted into a white opaque gelatinous mass.

Nitrat.

2. Nitric acid has no action on the red oxide of titanium, and scarcely any upon the metal; but it dissolves the carbonat, 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.

Muriat.

3. Muriatic acid dissolves titanium; but it has no effect upon its red oxide. The carbonat 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 oxy-muriatic acid, and the oxide precipitates, and is no longer soluble in muriatic acid, unless it be boiled in nitric acid. Hence they conclude, that the muriat contains titanium combined with a maximum of oxygen, and that the suboxide is incapable of uniting with muriatic acid.

4 and 5. When the phosphoric or arsenic acid is

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* Klaproth's *Beitrage*, i. 233.

dropt into the solution of titanium in acids, it occasions a white precipitate.

Carbonat.

6. When one part of red oxide of titanium and six parts of carbonat of potass 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 carbonat of titanium. According to the experiments of these chemists, it is composed of

75	white oxide
25	carbonic acid
100	

7 and 8. Oxalic and tartarous acids likewise occasion a white precipitate, but it is redissolved again almost as soon as formed *.

Genus XXI. Salts of Chromum.

This genus of salts is still altogether unknown; the small quantity of chromum hitherto obtained not having permitted chemists to examine the combinations which its oxides are susceptible of forming with acids. But the presence of this metal in solution may be ascertained by the following properties:

Characters.

1. Triple prussiat of potass occasions a green precipitate.

2. The infusion of nutgalls occasions a brown precipitate.

3. The hydrosulphuret of potass occasions a green precipitate, which a few drops of nitric acid change to yellow.

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* *Jour. de. Min.* No. xv. p. 1.

SECT. III.

REMARKS ON THE SALTS.

SUCH are the properties of all the salts which have been hitherto examined by chemists, and which amount to no fewer than 505. Great as this number is, it cannot be doubted that the class of salts will be considerably increased hereafter.

Importance of the salts.

Of these bodies, there are some, as alum, copperas, &c. which constitute the basis of different arts and manufactures, and which therefore are of sufficient importance to deserve an accurate examination even on their own account. Others, again, are the source from which chemists obtain many of the most valuable of their instruments of analysis; as nitre, common salt, phosphat of lime, sal ammoniac, sulphat of barytes, &c.; and therefore naturally claim the particular attention of all those who cultivate the science. But it must be allowed, that by far the greater number of saline bodies are at present of no apparent use whatever, either in the arts or in chemistry. At first sight it may appear a very useless piece of labour to be at the trouble of examining and describing these; but there are several reasons which render a precise knowledge of all the salts not only proper, but even necessary.

Were we to limit ourselves to the examination of those things whose usefulness is already known, there would be an end of all improvement. Every thing must be useless, as far as regards us, till its properties be known, and the purposes to which it may be applied ascertained. Many of those salts which we at present consider as of no utility, may hereafter be found of the greatest consequence, when their properties have been more completely investigated. This remark has been verified more than once within these few years. The muriat of lime, for instance, was formerly thrown away, but is now applied with great advantage to produce artificial cold; and the oxy-muriats, though a new class of salts, constitute an essential ingredient in the process of bleaching. Want of utility therefore is but a meagre reason for neglecting the examination of the salts, unless it could be demonstrated *a priori* that they never can be applied to any use.

But were we even certain that this were the case, still the examination of a great number of these salts would be indispensable: For those salts which are the most useful are seldom or never found in a state of purity; they are constantly mixed and contaminated with other salts, from which it is necessary to free them before they will answer the purposes to which they are usually applied. Now these foreign salts cannot be separated unless we be acquainted with them, at least sufficiently to know the effect of different agents upon them; that is, unless we be acquainted with their properties. Thus we see that it is not possible to obtain those salts which are really useful, without at the same time knowing the nature of many salts which have been applied to no use. Thus common salt is always mixed with muriat of magnesia, and cannot be obtained unless we understand the method of separating or decomposing that salt.

But it is not strictly true that many of the salts are ltogether useless. It may be affirmed, with the great-st truth, that, even at present, there is not one among hem, the knowledge of whose properties is not of some lvantage. One of the most important and difficult hings in chemistry is to ascertain exactly the nature nd composition of different bodies. Now this can on-y be done by observing the changes produced upon hem by other bodies, and the compounds which they re capable of forming. Thus if, on examining a sub-tance, I find, that when, combined with sulphuric acid, t forms a heavy insoluble white powder ; with muria-ic acid, a very soluble salt, which crystallizes in ta-les, and is insoluble in alcohol ; with phosphoric and xalic acid likewise an insoluble powder, &c.—I con-lude, without hesitation, that it is barytes. A sub-tance which dissolves in sulphuric acid, and forms a salt f a blue colour, crystallized in rhomboidal prisms, of n acrid taste and caustic, which forms with muriatic cid a green salt, which becomes blue when mixed with mmonia, and which when mixed with alkalies occa-ions a blue or green precipitate—I conclude to be cop-er. Thus it is the knowledge of the salts which the ifferent alkalies, earths, metals, and acids, are capable f forming, which enables us to discover their presence hen they enter as ingredients into different compounds. ere, then, is a reason for studying the properties of he salts, independent of their utility as individual bo-ies ; and it may be affirmed with truth, that chemical kill is in every case proportional to the extent of this nowledge.

The great number of saline bodies renders it a diffi-ult task to remember the properties of each. Indeed he thing would be impossible, were it not the salts naturally arrange themselves into certain groups, the individuals belonging to which all agree in certain general properties which may be remembered with facility; and after these general properties have indicated the group to which a given salt belongs, it is much easier to ascertain the species

Salts divided into two orders.

The salts may be divided conveniently into two orders, under one or other of which every salt is to be placed. These two orders constitute the two first Sections of this Chapter. The first order comprehends under it all the earthy and alkaline salts; the second order all the metalline salts.

First order.

The first order may be distinguished by the following characters: The salts belonging to this order are, either, 1. Soluble in water; and in that case the solution is not precipitated by hydrosulphuret of potass *, triple prussiat of potass †, or infusion of nutgalls ‡: or, 2, Insoluble in water; and in that case they are either soluble in muriatic acid, or become so when heated to redness, or fused with carbonat of potass; and the solution yields a precipitate when sulphuric acid is added, or if not, at least when potass is added The insoluble salts afford with borax, before the blow-pipe, a white glass or enamel.

Second order.

The second order may be distinguished by the following properties: The salts belonging to it are, either, 1. Soluble in water; in which case they afford a precipitate with hydrosulphuret of potass, triple prussiat

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* Except salts with base of alumina or zirconia.

† Except salts with base of yttria or zirconia.

‡ Except salts with base of yttria, glucina, or zirconia.

f potass*, and the infusion of nutgalls†: or, 2. Insouble in water; in which case, when fused with borax y the blow-pipe upon charcoal, they either afford a utton of metal, or form with the borax a coloured lass.

The first order is divisible into 32 genera; the salts elonging to which may be distinguished by the chaacters of these genera given in the first Section of this hapter. The species may be ascertained by the decription there given; but the investigation will be nuch facilitated by attending to the following observaions:

Characters of the species.

1. The species may be distinguished into two kinds; hose whose base is an *alkali*, and those which have an *arthy* base.

2. The alkaline salts are all soluble in water. Potass ccasions no precipitate of a white powder when added o the solution; neither does oxalic acid occasion any recipitate.

3. The salts with an ammoniacal base are all either issipated entirely, or converted into an acid when exosed to a red heat.

4. Many of the earthy salts are insoluble in water; white powder is precipitated from the soluble salts ither by the addition of potass or of sulphuric acid.

5. The salts whose base is barytes are all‡ insoluble n water, or nearly so, except six; namely, the nitrat, nuriat, acetite, lactat, benzoat, and prussiat; from the

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[*] Except salts of gold, platinum, antimony, and tellurium.

[†] Except salts of platinum, zinc, arsenic, and manganese.

[‡] Five of them are still unknown; namely, the oxy-muriat, molybdat, hromat, gallat, and sebat.

solutions of these, sulphuric acid occasions a white heavy insoluble precipitate.

6. All salts whose base is strontian are nearly insoluble in water, as far as they have been examined, except six; namely, nitrat, muriat, oxy-muriat, acetite, tartrite, and citrat. These also yield an insoluble white powder with sulphuric acid But the alkalies occasion no precipitate either in the solutions of barytic or strontian salts.

7. All salts whose base is lime are very sparingly soluble in water except ten; namely, nitrat, muriat, oxy-muriat, arseniat, acetite, malat, lactat. benzoat, prussiat, and sebat. The lime is precipitate from these solutions by oxalic acid, fixed alkalies, and by sulphuric acid, if the solution be concentrated, but not by ammonia.

8. The magnesian salts are all soluble in water except seven; namely, phosphite, fluat, carbonat, oxalat, tartrite, mucite, and camphorat. Their solution yields a precipitate with ammonia, which forms with sulphuric acid a very soluble bitter salt.

9. The alkaline earths form with acids a greater number of salts soluble in water in proportion as the alkaline properties of the earth diminish. Barytes forms salts, the greater number of which are insoluble; strontian seems to form a greater number of soluble salts than barytes; lime forms a still greater number; and almost the whole of the magnesian salts are soluble in water.

10. Six of the aluminous salts are insoluble in water; namely, sulphite, phosphat, borat, arseniat, tungstat, and mucite. The aluminous salts are all deprived of their acid by heat. With potass they yield a precipi-

Chap. III.

tate which dissolves in sulphuric acid; and when sulphat of potass is added to the solution, crystals of alum are gradually obtained. The aluminous salts let fall a precipitate when hydrosulphuret of potass is dropt into their solution.

11. The salts of yttria are decomposed by heat and by alkalies; they have a sweetish astringent taste; triple prussiat of potass and infusion of nutgalls occasion a precipitate when poured into their solutions.

12. The salts of glucina are decomposed by heat and by alkalies: they have a sweetish taste. The precipitate separated from them by alkalies, redissolved in nitric or muriatic acid, is again precipitated by the infusion of nutgalls, but not by triple prussiat of potass.

13. The zirconian salts have an austere taste: they are decomposed by heat and by alkalies. The precipitate separated from them by these last bodies, when redissolved in muriatic acid, is precipitated by hydrosulphuret of potass, triple prussiat of potass, and by the infusion of nutgalls.

The second order of salts is divisible into 21 genera, each of which may be recognised by the characters given in the second Section. The species in these genera may be distinguished from each other by the properties of the different acids which form them; and these properties have been enumerated in the first Section as the characteristic marks of the genera of earthy and metallic salts.

The following Table, which gives a synoptical view of the properties of the most important salts, will add considerably to the facility of distinguishing the different species.

Book II. Division II.

Salts.	Taste.	Figure of Crystals.	Action of Air.	Solubility in 100 parts Water at 60°.	Solubility in 100 parts Water at 212°	Action of Heat.
Sulphat of barytes	None	Rhomboidal prisms	None	0.002	0.	Decrepitates
potass	Bitter	Six-sided prisms	None	6.25	20.	Decrepitates
soda	Bitter	Six-sided prisms	Effloresces	37.	125.	Watery fusion
strontian	None	Rhomboidal prisms	None	0.00	0.02	
lime	Little	Rhomboidal prisms	None	0.2	0.22	Decrepitates
ammonia	Bitter	Six-sided prisms	Subdeliquesces	50.	100.	Decrepitates and melts
magnesia	Bitter	Four-sided prisms	Effloresces	100.	133.	Watery fusion
Alum	Astringent	Octahedrons	Little	5.	133.	Watery fusion
Sulphite of barytes	None	Tetrahedrons	Chang. to sulph.	0.	0.	
lime	None	Six-sided prisms	Effloresces	0.125		Falls to powder
potass	Sulphur.	Rhomboidal plates	Effloresces	100.		Decrepitates
soda	Sulphur.	Four-sided prisms	Effloresces	25.	100.	Watery fusion
ammonia	Sulphur.	Six-sided prisms	Subdeliquesces	100.		Decrepitates
magnesia	Little	Tetrahedrons	Effloresces	5.		Swells
Nitrat of barytes	Acrid	Octahedrons	None	8.	25.	Decrepitates
potass	Cooling	Six-sided prisms	None	14.25	100.	Melts
soda	Cooling	Rhomboidal prisms	Subdeliquesces	33.	100 +	Melts
strontian	Pungent	Octahedrons	Little	100.	200.	Decrepitates and melts
lime	Bitter	Six-sided prisms	Deliquesces	400.	Any quantity	Watery fusion
ammonia	Acrid	Six-sided prisms	Deliquesces	50.	200.	Melts
magnesia	Bitter	Rhomboidal prisms	Deliquesces	100.	100 +	Watery fusion
Muriat of barytes	Astringent	Four-sided prisms	None	20.		Decrepitates
potass	Bitter	Cubes	None	33.		Decrepitates
soda	Salt	Cubes	None	35.42	36.16	Decrepitates
strontian	Sharp	Six-sided prisms	Little	150.	Any quantity	Watery fusion
lime	Bitter	Six-sided prisms	Deliquesces	200.		Watery fusion
ammonia	Acrid	Four-sided pyramids	Subdeliquesces	33.		Sublimes
magnesia	Bitter	Needles	Deliquesces	100.		Watery fusion

Salts.	*Taste.*	*Figure of Crystals.*	*Action of Air.*	*Water* at 60°	*Water* at 212°	*Action of Heat.*
Oxy-muriat of potass -	Cooling	Rhomboidal plates	None	6.	40.	Gives out oxygen
Phosphat of barytes -	None	o	None	o.	o.	Little
strontian -	None	o	None	o.	o.	Little
lime -	None	Six-sided prisms	None	o.	o.	Little
potass -	Salt	A gelatinous mass	Deliquesces	Very	soluble	Watery fusion
soda -	Salt	Rhomboidal prisms	Effloresces	25.	50.	Watery fusion
ammonia -	Cooling	Four-sided prisms	None	25.	25 +	Watery fusion
magnesia -	Cooling	Six-sided prisms	Effloresces	6.6		Falls to a powder
Fluat of lime - -	None	Cubes	None	o.	o.	Decrepitates
Borax - -	Styptic	Six-sided prisms	Subeffloresces	8.4	16.8	Watery fusion
Carbonat of barytes -	None	Various	None	0.023	0.043	Little
strontian -	None		None	o.	0.065	Little
lime -	None	Rhomboidal prisms	None	o.	o.	Decrepitates
potass -	Alkaline	Four-sided prisms	None	25.	$83\frac{1}{3}$	Watery fusion
soda -	Alkaline	Octahedr truncated	Effloresces	50.	100 +	Watery fusion
magnesia -	None	Six-sided prisms	Effloresces	2.		Decrepitates
ammonia -	Urinous	Irregular	None	50 +	100.	Evaporates
Acetite of barytes -	Bitter	Needles	Subeffloresces			Decomposed
potass -	Hot	Plates	Deliquesces	100.		Melts
soda -	Sharp	Striated prisms	None	35.		Melts
strontian -			None		40.8	Decomposed
lime -	Bitter		None			Decomposed
ammonia -	Cool	Slender prisms	Deliquesces	Very	soluble	Melts and sublimes
magnesia -	Sweetis	o	Deliquesces	Very	soluble	Decomposed
Tartar - - -	Acid	Irregular prisms	None	$1\frac{2}{3}$	$3\frac{1}{3}$	Melts
Tartrite of potass -	Bitter	Four-sided prisms	None	25.		Melts
Tartrite of potass-and-soda	Bitter	Eight-sided prisms	Effloresces	25.		Melts

CHAP. IV.

OF HYDROSULPHURETS.

Properties of sulphurated hydrogen.

Sulphurated hydrogen gas possesses the properties of an acid. It is absorbed by water in considerable quantities, and the solution reddens vegetable blues; it combines also with alkalies and earths, and with several metallic oxides. The greater number of these properties were first pointed out with precision by Mr Kirwan; but they were afterwards much more fully developed by Berthollet.

Liquid sulphurated hydrogen, or sulphurated hydrogen gas dissolved in water, is not decomposed by exposure to the air; but the gas is gradually separated and carried off by the air without decomposition. When sulphurous acid is mixed with this solution, both the sulphurated hydrogen and the acid are in a great measure decomposed; the hydrogen of the one combines with the oxygen of the other, and forms water; while the sulphur of both is precipitated, as was first observed by Fourcroy, and more fully ascertained by Berthollet. Nitric acid produces the same effect unless it be too much diluted with water. Hence the reason that sulphur precipitates when that acid is mixed with water, holding sulphurated hydrogen in solution, as Bergman first observed. Oxy-muriatic acid, on the other hand, converts the sulphurated hydrogen into water and sulphuric acid, by supplying both of its component parts with oxygen.

Precipitates metals.

Sulphurated hydrogen has a strong action on the greater number of metallic oxides; its hydrogen abstracts oxygen from these bodies, and thus either brings them to the metallic state or to a minimum of oxygen; while at the same time its sulphur combines with the metal thus regenerated. Hence the reason of the change produced upon the solutions of the metallic salts by the infusion of liquid sulphurated hydrogen. All the genera of metallic salts are precipitated by this substance excepting five; namely, those which contain the following metals:

1. Iron,	4. Manganese,
2. Nickel,	5. Titanium: and also
3. Cobalt,	6. Molybdenum*.

Nature of the precipitates.

Berthollet and Proust have shewn, that the oxides of these metals are reduced by sulphurated hydrogen to a minimum of oxygen; but as in that state they have but little affinity for sulphur, they continue combined with the acids which held them at first in solution. Tin, on the other hand, which at a minimum of oxidation has a strong affinity for sulphur, is precipitated, though sulphurated hydrogen only reduces it to a minimum of oxidation.

The metallic solutions differ considerably in the facility with which they afford precipitates with sulphurated hydrogen; and Mr Proust has shewn 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 solu-

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* When in the state of an acid and combined with an alkali.

tion together in nitric acid, sulphurated 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 sulphurated hydrogen. The colours of these different precipitates may be seen in the following TABLE:

Gold	Yellow
Silver	Black
Mercury	Black
Copper	Black
Tin	Brown
Lead	Black
Zinc	Yellow
Bismuth	Black
Antimony	Orange
Arsenic	Yellow
Molybdenum	Brown

Super-sulphurated hydrogen.

Sulphurated hydrogen has the property of combining with sulphur, and of forming a compound which has the appearance of a yellow oil. It was first observed by Scheele [†]; and Berthollet [‡], who first examined its nature, has given it the name of *hydrogenated sulphur*. When hydrogenated sulphuret of potass is poured by little and little into muriatic acid, scarcely any sulphurated hydrogen gas is exhaled, but hydrogenated sulphur gradually precipitates to the bottom of the vessel. This substance, when heated, easily allows the sulphu-

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[*] *Jour. de Phys.* li. 174.

[†] Scheele *on Fire*, p. 192. Engl. Trans.

[‡] *Ann. de Chim.* xxv. 247.

rated hydrogen gas to exhale, and is converted into sulphur. The same change takes place when it is exposed to the open air.

Thus we see that sulphur and hydrogen are capable of combining in two proportions, or, which is the same thing, that hydrogen combines with two doses of sulphur. The first of these constitutes sulphurated hydrogen gas, or hepatic air; which, according to Thenart, is composed of about 29 hydrogen
71 sulphur

100

The addition of another dose of sulphur constitutes *hydrogenated sulphur*, which Mr Kirwan has with great propriety denominated *super-sulphurated hydrogen*; a name which certainly ought to be adopted *. Both of these substances combine with different bases, and constitute very peculiar genera of compounds, which deserve a particular examination on account of the important purposes which they serve in analysis. The combinations which sulphurated hydrogen forms with bases, have been called by Berthollet *hydrosulphurets*, and the compounds formed by super-sulphurated hydrogen, *hydrogenated sulphurets* †.

Hydrosulphurets,

The alkaline and earthy hydrosulphurets may be formed by dissolving or mixing these bases respectively

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* Kirwan *on Mineral Waters*, p. 11.

† This denomination, as Kirwan has well observed, is very improper, as it does not indicate the composition, and is exceedingly unwieldy. Mr Kirwan uses the term *hepatule* instead of *hydrosulphuret*, and *hepar* for *hydrogenated sulphuret*. *Hepar* would certainly be far preferable, were it not unluckily ambiguous, having been used likewise to denote the sulphurets. However, I shall use it occasionally in Kirwan's sense.

How formed.

with water, and causing sulphurated 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 sulphurated 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. They are colourless and transparent while kept in close vessels, but when exposed to the air, they soon become coloured. This change is produced by the decomposition of part of their sulphurated hydrogen by the air. Its hydrogen combines with the oxygen of the air, and forms water, while the sulphur is set at liberty, and thus darkens the colour. Hitherto only the alkalies, alkaline earths, and magnesia, have been combined with sulphurated hydrogen. Alumina and zirconia do not combine with it at all: glucina and silica have not been tried.

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 sulphurated 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 sulphurated 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 sulphurated hydrogen is diminished, and that of the sulphur increased to a certain point, the sulphur and the hydrogen combine equally with oxygen.

If sulphuric or muriatic acids be poured upon a hydrosulphuret after it has been for some time exposed to the air, a quantity of sulphurated hydrogen gas exhales, sulphur is deposited, and after an interval of time sulphurous acid is disengaged. It is therefore sulphurous, and not sulphuric acid, which is formed while the hydrosulphuret spontaneously absorbs oxygen. This acid, however, is not perceptible till after a certain interval of time, when separated from the hydrosulphuret by means of an acid; because as long as it meets with sulphurated hydrogen a reciprocal decomposition takes place. The oxygen of the acid combines with the hydrogen of the gas, and the sulphur of both is precipitated.

Properties.

These hydrosulphurets have not been sufficiently examined to admit of a detailed description of each. None of them seem capable of crystallizing except the hydrosulphuret of barytes. If a solution of sulphuret of barytes in water, or, more properly, if hydrogenous sulphuret of barytes be evaporated, a great number of confused crystals are formed; if these be separated quickly by filtration, and placed upon blotting paper to dry, a white crystalline substance is obtained, which is hydrosulphuret of barytes.

The affinities of the alkalies and earths for sulphurated hydrogen appear from the experiments of Berthollet to be as follows:

Affinities.

Barytes,
Potass,

Soda,
Lime,
Ammonia,
Magnesia,
Zirconia.

The hydrogenated sulphurets or hepars of alkalies and earths 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, super-sulphurated 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 hydrogenated sulphuret *. When prepared by the first process, they contain an excess of sulphur, which seperates when sulphurated hydrogen is made to pass through them.

Precipitate metals.

The hydrosulphurets and hydrogenated sulphurets have the property of precipitating all metallic bodies 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 sulphurated hydrogen, 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 alumina and zirconia

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* *Ann. de Chim.* xxv. 242.

is occasioned by the base of the hydrosulphuret, while the sulphurated hydrogen is exhaled in the state of gas, not being susceptible of combining with these earths. Hydrosulphuret or hydrogenated sulphuret of potass 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:

Metals	Precipitate by Hydrosulphuret of Potass	Hydrogenated sulphuret of Potass.
Gold	Yellow	Yellow.
Silver	Black	Black.
Mercury	Brown black	Brown, becoming black.
Copper	Black	Brown.
Iron	Black	Black, becoming yellow.
Tin	Black	
Lead	Black	White, becoming black
Nickel	Black	
Zinc	White	White.
Bismuth	Black	Black.
Antimony	Orange	Orange-yellow.
Tellurium	Black ?	Deep brown or black.
Arsenic	Yellow	Yellow.
Cobalt	Black	
Manganese	White	
Uranium	Brown	Brownish-yellow *.
Titanium	Glass-green	Bluish-green *.
Chromum	Green	

The nature of these precipitates has hitherto been very much overlooked by chemists. The subject, however,

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* In these experiments hepar of ammonia was used by Klaproth.

deserves a very particular examination. The following observations will give a pretty complete view of the present state of our knowledge.

Of the precipitates.

1. Stahl ascertained long ago that sulphuret of potass is capable of oxidating gold when melted with it in a crucible, and that the mixture is soluble in water and has a yellow colour; but the nature of this combination has not hitherto been investigated *.

2. Lewis has ascertained that platinum is attacked when treated in the same way by sulphuret of potass; but the nature of the combination is still unknown.

3. Silver is capable of combining with sulphurated hydrogen; but the black precipitate occasioned by pouring a hydrosulphuret into a solution of silver, seems to consist chiefly of sulphuret of silver.

4. The same observation applies to mercury; but Berthollet has shewn that the black mercurial sulphuret contains also a portion of sulphurated hydrogen.

5. Copper is capable of existing in the state of a hydrogenated sulphuret; its precipitate seems to be nearly in that state, or at least to be a sulphuret with excess of sulphur.

6. Iron also forms a hydrogenated sulphuret, which is soluble in water, and has a deep green colour; but the precipitate of that metal by a hydrosulphuret is probably the black oxide combined with sulphur.

7. The precipitates of tin, lead, and zinc seem to be sulphurets.

8. The precipitate produced in antimonial solutions by hydrosulphuret of potass, is the only one of them all which has been hitherto examined with attention. It has an orange colour, and has been shewn by Ber-

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* Stahl's *Opusc. Chim. Phys. Med.* p. 606.

llet and Thenart to be a compound of oxide of anti-
ny and super-sulphurated hydrogen. This compound,
der the name of *kermes mineral*, acquired very great
ebrity for its medical virtues about the beginning of
18th century. The method of preparing it was
t discovered by Glauber, and afterwards by Lemery
Elder; but it was first brought into vogue in France
a priest called Simon, who was taught the secret of
paring it by La Ligerie, a surgeon, to whom it had
n communicated by a pupil of Glauber. The French
ernment purchased the secret from La Ligerie, and
blished the process in 1720. It was very tedious
l ill contrived, consisting in boiling repeatedly a very
uted solution of potass on sulphuret of antimony;
mall portion of kermes precipitated as the solution
led. The process of Lemery was therefore adopt-
by apothecaries. It is the following:

Kermes mineral.

ixteen parts of sulphuret of antimony, eight parts
otass of commerce, and one part of sulphur, are tri-
ated together in a mortar, melted in a crucible, and
mass poured into an iron vessel. When cold it is
nded, and boiled in a sufficient quantity of water,
the solution is filtered while hot. On cooling, it
osites the kermes abundantly in the state of a yel-
powder, which is edulcorated with a sufficient
ntity of water, and dried: Or six parts of potass
y be dissolved in twenty parts of water, and to
solution, previously made boiling hot, one part of
nded sulphuret of antimony may be added. The
ition, well agitated, boiled for seven or eight mi-
es, and filtered while hot, deposites on cooling abun-
ce of kermes.

his powder occupied a good deal of the attention of chemists. Bergman first demonstrated that it contained sulphurated hydrogen; but it was Berthollet wh first pointed out its true composition. From the analysis of Thenart it follows that it is composed of

20.30	sulphurated hydrogen
4.15	sulphur
72.76	brown oxide of antimony
2.79	water and loss
100.00*	

When this substance is exposed to the air, it graduall absorbs oxygen, and becomes white.

Sulphur auratum.

After the mineral kermes has precipitated from it solution prepared by either of the formulas above described, if an acid be added to the liquid, another pr cipitate is produced of an orange colour, hence calle *sulphur auratum*. According to the analysis of Thenart, it is composed of

17.87	sulphurated hydrogen
68.30	orange oxide
12.00	sulphur
98.17†	

The sulphur seems to be only mechanically mixed consequently the *sulphur auratum* is a hydrosulphure of antimony. Goettling has proposed the followin process for obtaining this compound: Two parts c sulphuret of antimony and three parts of sulphur we mixed are dissolved in a boiling solution of pure potass; the solution is then diluted with water, and precipitated by means of weak sulphuric acid‡.

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* *Ann. de Chim.* xxxii. 268.

† Ibid.

‡ Bergman iii. 172.

Chap. V.

CHAP. V.

OF SOAPS.

THE fixed oils have the property of combining with alkalies, earths, and metallic oxides, and of forming with these bodies a class of compounds which have received the name of *soaps*. As these soaps differ from each other very materially, according as their base is an alkali, an earth, or an oxide, it will be proper to consider each set separately. This will be the subject of the three following Sections.

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 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*, σαπων) 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 strongly impregnated with the pure alkali. This water is then drawn off by means of a stop-cock, 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-cock, and called the *second ley*.

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* Beckman s *History of Inventions*, iii. 239.— A similar word is still used by the common people of Scotland.

† Pliny, lib. xviii. c. 51.

Another portion of water is poured on ; and after
tanding a sufficient time, is drawn off like the other
wo, and called the *third ley*.

Another portion of water may still be poured on, in
rder to be certain that the whole of the soda is dissol-
ed ; and this weak ley may be put aside, and employ-
d afterwards in forming the first ley in subsequent o-
erations.

A quantity of oil, equal to six times the weight of
e soda used, is then to be put into the boiler, together
ith a portion of the *third* or *weakest ley*, and the mix-
re must be kept boiling and agitated constantly by
eans of a wooden instrument. The whole of the third
y is to be added at intervals to the mixture; and after
is consumed, the *second ley* must be added in the
me manner. The oil becomes milky, combines with
e alkali, and after some hours it begins to acquire
nsistence. A little of the *first ley* is then to be added,
t forgetting to agitate the mixture constantly. Por-
ons of the first ley are to be added at intervals ; the
apy substance acquires gradually greater consistency,
d at last it begins to separate from the watery part
the mixture. A quantity of common salt is then to
added, which renders the separation much more com-
ete. The boiling is to be continued still for two
urs, and then the fire must be withdrawn, and the li-
or must be no longer agitated. After some hours
pose the soap separates completely from the watery
rt, and swims upon the surface of the liquor. The
atery part is then to be drawn off ; and as it contains
quantity of carbonat of soda, it ought to be reserved
r future use.

The fire is then to be kindled again ; and, in order

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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 i to separate the water from the soap; for common sal has a stronger affinity for water than soap has.

Olive oil has been found to answer best for makin soap, and next to it perhaps tallow may be placed: bu a great variety of other oils may be employed for tha purpose, as appears from the experiments of the Frenc chemists above quoted. They found, however, tha linseed oil and whale oil were not proper for makin *hard soaps*, though they might be employed with advantage in the manufacture of *soft soaps*. Whale oil h been long used by the Dutch for this last purpose.

Soap may also be made without the assistance heat; but in that case a much longer time and a larg proportion of alkali is necessary.

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* See the Memoir of Darcet, Lelievre, and Pelletier, in the *An* *Chim.* xix. 253.

Chap. V.

Sophistication.

Manufacturers have contrived various methods of sohisticating soap, or of adding ingredients which inrease its weight without increasing its value. The most common substance used for that purpose is water; which may be added in considerable quantities, especially to soap made with tallow (the ingredient used in this ountry), without diminishing its consistency. This raud may be easily detected, by allowing the soap to e for some time exposed to the air. The water will vaporate from it, and its quantity will be discovered y the diminution of the weight of the soap. As soap ophisticated in this manner would lose its water by beng kept, manufacturers, in order to prevent that, keep heir soap in saturated solutions of common salt; which o not dissolve the soap, and at the same time, by preenting all evaporation, preserve, or rather increase, the weight of the soap. Messrs Darcet, Lelievre, and Peletier, took two pieces equal in weight of soap sophistiated in this manner, and placed the one in a dry place n the open air, and the other in a saturated solution of ommon salt. After a month the first had lost 0.56 of s weight, the other had gained about 0.10 parts *. Various other methods have been fallen upon to sophiscate soap; but as they are not generally known, it would be doing an injury to the public to describe hem here.

Analysis.

Different chemists have analysed soap, in order to asertain the proportions of its ingredients; but the reult of their experiments is various, because they used oap containing various quantities of water. From the xperiments of Darcet, Lelievre, and Pelletier, it ap-

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* *Ann. de Chim.* xix. 330.

pears that soap newly made and exposed to sale contains

60.94 oil
8.56 alkali
30.50 water

100.00

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 Potass or Soft Soap.*

Formation.

POTASS 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 potass 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 potass; 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 mehod of making hard soap with potass. Their method s this: After forming the soap in the manner above decribed, they add to it a large quantity of common salt, oil it for some time, and the soap becomes solid when ooled in the usual way. That this method may be ractised with success has been ascertained by Messrs Darcet, Lelievre, and Pelletier; but then the hard soap hus formed does not contain potass but soda: for when he common salt (muriat of soda) is added, the potass f the soap decomposes it, and combines with its muritic acid, while at the same time the soda of the salt ombines with the oil, and forms hard soap: and the nuriat of potass formed by this double decomposition is lissolved in water, and drawn off along with it *.

Soap of wool.

Chaptal has lately proposed to substitute wool in lace of oil in the making of soap. The ley is formed n the usual manner, and made boiling hot, and shreds f woollen cloth of any kind are gradually thrown into ; they are soon dissolved. New portions are to be dded sparingly, and the mixture is to be constantly gitated. When no more cloth can be dissolved, the oap is made †. This soap is said to have been tried with uccess. It might doubtless be substituted for soap with dvantage in several manufactures, provided it can be btained at a cheaper rate than the soaps at present mployed.

Fish soap.

Some time ago a proposal was made to substitute the nuscles of fish instead of tallow or oil in the manufacure of soap; but the experiments of Mr Jamieson have lemonstrated that they do not answer the purpose ‡.

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* *Ann. de Chim.* xix. 322.

† Ibid. xxi. 27.

‡ Nicholson's *Journal*, iii. 113.

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Sp. 3. *Soap of Ammonia.*

This soap was first particularly attended to by Mr Berthollet. It may be formed by pouring carbonat 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 muriat 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.

SECT. II.

OF EARTHY SOAPS.

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 nite together and form an earthy soap. Hence the eason that all waters holding an earthy salt are unfit or washing. They decompose common soap, and form n earthy soap insoluble in water. These waters are vell known by the name of *hard* waters. Hitherto the arthy soaps have been examined by Mr Berthollet nly.

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. Carbonat 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 sulphat 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 solu-

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* Thouvenel.

† Berthollet, *Mem. Par.* 1780, or Nicholson's *Journal*, i. 170.

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tions of alum and of common soap. It is a flexible soft substance, which retains its suppleness and tenacity when dry. It is insoluble 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 muriat 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

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* Berthollet, *Mem. Par.* 1780, or Nicholson's *Journal*, i. 179.

adually becomes deeper, especially if exposed to the n or to heat. It dissolves very well in oil, but sparigly in alcohol. It readily becomes soft and fluid hen heated [*].

2. *Soap of zinc* may be formed by mixing together a lution of sulphat of zinc and of soap. It is of a white lour, inclining to yellow. It dries speedily, and bemes friable [†].

3. *Soap of cobalt*, made by mixing nitrat of cobalt d common soap, is of a dull leaden colour, and dries ith difficulty, though its parts are not connected. Mr Berthollet observed, that towards the end of the ecipitation there fell down some green coagula, much ore consistent than soap of cobalt. These he suppo-l to be a soap of nickel, which is generally mixed with balt [‡].

4. *Soap of tin* may be formed by mixing common ap with a solution of tin in nitro-muriatic acid. It is iite. Heat does not fuse it like other metallic soaps, t decomposes it [§].

5. *Soap of iron* may be formed by means of sulphat iron. It is of a reddish brown colour, tenacious, d easily fusible. When spread upon wood, it sinks and dries. It is easily soluble in oil, especially of rpentine. Berthollet proposes it as a varnish [‖].

6. *Soap of copper* may be formed by means of sul-at of copper. It is of a green colour, has the feel of esin, and becomes dry and brittle. Hot alcohol renrs its colour deeper, but scarcely dissolves it. Ether ssolves it, liquefies it, and renders its colour deeper and

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[*] Berthollet, *Mem. Par.* 1780, or Nicholson's *Journal*, i. 170.

[†] Ibid. [‡] Ibid. [§] Ibid. [‖] Ibid.

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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 acetite 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 nitrat 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 muriat 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 sulphat 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 be-

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* Berthollet, *Mem. Par.* 1780, or Nicholson's *Journal*, i. 170.

† Ibid. ‡ Ibid. § Ibid. || Ibid.

ng easily kneaded when heated with the hand, to adhere irmly to the skin, but to be capable of being removed 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 fenugrec, 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

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* *Ann. de Chim.* xxxiii. 50.

† Deyeux, Ibid.

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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 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;

ving either to the absorption of oxygen, or to some ange produced in their component parts by the action the air.

CHAP. VI.

REMARKS ON THE SECONDARY COMPOUNDS.

THE secondary compounds are incomparably more nu- ierous than the primary; because they approach much arer the actual component parts of the mineral, ve- etable, and animal kingdoms. Indeed a very consider- ble proportion of them exist native, especially in the ineral kingdom; and that number will no doubt in- ease as the science of chemistry extends its bounds.

Secondary compounds resemble simple bodies.

Few of the secondary compounds have that activity, at violent action, upon other bodies, which distin- uish the primary compounds. In this respect they ar a strong resemblance to the simple substances. ulphur, for instance, is a body which has scarcely any ste, and which acts but feebly upon animals, and not all perceptibly upon vegetables and minerals; and oxy- en, though it undoubtedly merits the appellation of an tive body, shews neither in its taste nor in its action animals and vegetables any thing which deserves the ame of acrid or caustic; but sulphuric acid, though mposed of these two inoffensive bodies, is one of the ost active and corrosive substances known, and burns d decomposes almost all the animal and vegetable

Book II. Division II.

bodies which are exposed to its influence. Potass is, if possible, still more corrosive; even the hardest mineral is unable to resist its action. But sulphat of potass, though composed of these two formidable bodies, is not more active than sulphur itself. This singular correspondence between simple substances and secondary 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 gaseous

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; none of them, as far as is known, containing more than two component parts, if we omit the consideration of caloric and light altogether; or three component parts, if we include these bodies.

Or combustible.

None of the secondary compounds are, properly speaking, combustible. The soaps, indeed, and the vegetable-acid salts, are susceptible of undergoing a kind of combustion, but not till they have been previously decomposed by heat; and even then their combustion is not to be compared to that of some of the simple substances and primary compounds. Two genera of salts, namely, the nitrats and oxy-muriats, are supporters of combustion in a remarkable degree, occasioning violent detonations when triturated or heated along with com-

ustibles. Many of the metallic salts are doubtless
isceptible of supporting combustion as well as these
enera, though hitherto the experiment has not been
ied except upon a small number.

Better known than other bodies.

The secondary compounds have been investigated
ith more precision than any other class of bodies be-
onging to chemistry; and their formation and decom-
osition are more completely in the power of the che-
mist. The greater number of them may be formed
nd decomposed at pleasure; and approaches have been
made towards ascertaining the proportions of the com-
onent parts of several of them. Accordingly it is from
hem that almost all our notions of the nature of affinity
ave been derived. It is to them that we have always
ecourse to illustrate these notions, or to put them to
he test of experiment. What have been called *tables*
f affinity, are nothing else than lists of the substances
y which certain secondary compounds may be decom-
osed, or of the precipitations which take place when
ifferent secondary compounds are mixed together. It
as necessary therefore to be acquainted with these bo-
ies, and to know the mutual changes which they are
apable of producing on each other; the decompositions
f which they are susceptible, and the proportions of
eir component parts, before entering upon the consi-
eration of *affinity;* which may be considered as consti-
uting in reality the whole of the scientific part of che-
mistry, and as comprehending under it the general prin-
iples to which the immense mass of facts enumerated
n the two preceding Books may be referred, and under
hich they may be arranged. We are now therefore
repared for entering upon this important subject, which
ill employ the whole of the succeeding Book.

BOOK III.

OF

AFFINITY.

Book III. IN the two preceding Books the different substances which occupy the attention of the chemists have been enumerated, their properties have been described, and the changes which they produce on each other have been fully detailed. We are thus in possession of the immense body of facts of which the science of chemistry is composed; they have been arranged in that order which seemed most proper for shewing their mutual dependence on each other; and referred to a small number of general heads, that they might be remembered with facility or consulted without difficulty. It were to be wished that chemical phenomena could be referred to a few general laws, and shewn to be the necessary results of these laws. It were to be wished that we knew the nature of these laws so precisely, as to be able to foretel beforehand the changes which result from the mutual action of bodies in every particular circumstance. This would save us the trouble of learning in detail an immense number of insulated facts which at

Chemical laws

esent are necessary for the practice of chemistry ; it ould enable us to apply the science with more effect the arts and manufactures; it would enable us to ace the chemical changes which are going on in the mosphere and the earth to their origin, and to foree the future changes to which they are liable; and us to form what has hitherto been attempted in vain, complete theory of meteorology and geology.

Still imperfectly known.

Unfortunately the efforts of philosophers to establish nese general principles have not hitherto been attendd with complete success ; partly owing to the difficuly of the subject, and partly to the unaccountable neligence of the greater number of chemists who have een more anxious to ascertain particular facts than to nvestigate general principles, and who have often seemd to look upon general principles as altogether foreign o their science. Happily this has not been the case with all chemists. Several, and these the most illusrious, have carefully classified the phenomena, and reerred them under general heads ; and if they have not succeeded in discovering laws sufficiently comprehensive to include all the chemical phenomena, have at least pointed out several pretty general ones, from the knowledge of which the mutual action of many bodies on each other may, in not a few cases, be foreseen, even prior to experiment. Among these philosophers, none stands higher than Bergman, who was not less distinguished by his industry and enthusiasm, than by his enlarged views and the happy acuteness with which he drew general conclusions. To Black and Lavoisier we are indebted for two of the most general and most important laws hitherto discovered in chemistry. Much has been done by Kirwan, whose profound knowledge, fortunately for the science, almost constantly leads him to general views. Morveau has been no less distinguished in this important career; with a mind capable of the most comprehensive range, and the most profound views, he has classified the most difficult phenomena, and thrown light upon the abstrusest part of the science. And Berthollet has lately reviewed the general doctrines of chemistry with his usual sagacity; and has not only corrected various errors which had passed current without detection, but has pointed out several new laws of very great importance.

The general principles of chemistry shall form the subject of this Third Book, which will be divided into four Chapters. In the *first* Chapter we shall consider the nature of AFFINITY in general; in the *second*, we shall examine the affinity which HOMOGENEOUS bodies exert on each other; in the *third*, the affinity exerted by HETEROGENEOUS bodies; and in the *fourth*, the nature of REPULSION, which often acts as an antagonist to affinity.

CHAP. I.

OF AFFINITY IN GENERAL.

Attraction

. All the great bodies which constitute the solar ystem are urged towards each other by a force which reserves them in their orbits and regulates their moions. This force has received the name of *attraction*. ts nature is unknown: whether it be inherent in these odies themselves, or the consequence of some foreign gent, are questions altogether beyond the reach of hilosophy, because we have no method of deciding he point. One would be more inclined to the first upposition than to the other, as we can conceive no oreign agent sufficient to explain the planetary motions nless an intelligent one; and for any thing which we now to the contrary, it was as easy for the Creator o have bestowed on the planets the power of acting on ach other at a distance, as the power of being acted on nd receiving motion from other substances.

Universal.

2. Sir Isaac Newton demonstrated, that this planetary ttraction is the same with *gravitation*, or that force by vhich a heavy body is urged towards the earth; that it is ossessed, not only by the planets as wholes, but by all heir component parts also; that it is mutual; that it xtends to indefinite distances; and that all bodies, as ar as is known, are possessed of it.

3. When two bodies are brought within a certain

Book III.

distance, they adhere together, and require a considerable force to separate them. This is the case, for instance, with two polished pieces of marble or glass. When a piece of metal, or indeed almost any body whatever, is plunged into water and drawn out again, its surface is moistened, that is to say, part of the water adheres to it. When a rod of gold is plunged into mercury, it comes out stained indelibly of a white colour, because it retains and carries with it a portion of the mercury Hence it is evident that there is a force which urges these bodies towards each other and keeps them together; consequently there is an attraction between them. Bodies, therefore, are not only attracted towards the earth and the planetary bodies, but towards each other. The nature of this attraction cannot be assigned any more than that of gravitation; but its existence is equally certain, as far at least as regards by far the greater number of bodies.

4. In all cases we find the particles of matter united together in masses, differing indeed from each other in magnitude, but containing all of them a great number of particles. These particles remain united, and cannot be separated without the application of a considerable force; consequently they are kept together by a force which urges them towards each other, since it opposes their separation. Consequently this force is an *attraction*.

Thus we see that there is a certain unknown force which urges bodies towards each other; a force which acts not only upon large masses of matter as the sun and the planets, but upon the smaller component parts of these bodies, and even upon the particles of which these bodies are composed. Attraction, therefore, as far as we know, extends to all matter, and exists mu-ually between all matter. It is not annihilated at how reat a distance soever we may suppose bodies to be laced from each other, neither does it disappear, hough they be placed ever so near each other. The ature of this attraction, or the cause which produces t, is altogether unknown, but its existence is demontrated by all the phenomena of nature.

Ascribed to impulsion,

5. This attraction was long accounted for, by supposing that there existed a certain unknown substance which impelled all bodies towards each other; a hypothesis to which philosophers had recourse, from an opinion long admitted as a first principle, "that no body can act where it is not;" as if it were more difficult to conceive why a change is produced in a body by another which is placed at a great distance, than why it is produced by one which is situated at a small distance. It is not only impossible to explain the phenomena of attraction by impulsion, but it is as difficult to conceive how bodies should be urged towards each other by the action of an external substance, as how they should be urged towards each other by a power inherent in themselves. The fact is, that we can neither comprehend the one nor the other; nor can any reason be assigned why the Almighty might not as easily bestow upon matter the power of acting upon matter at a distance, as the power of being acted upon and changed by matter in actual contact.

But without reason.

But farther, we have no reason for supposing that bodies are ever in any case actually in contact. For all bodies are diminished in bulk by cold, that is to say, their particles are brought nearer each other, which would be impossible, unless they had been at some distance before the application of the cold. Almost all bodies are diminished in bulk by pressure, and consequently their particles are brought nearer each other; and the diminution of bulk is always proportional to the pressure. Newton has shown that it required a force of many pounds to bring two glasses within the 800th part of an inch of each other; that a much greater was necessary to diminish that distance; and that no pressure whatever was capable of diminishing it beyond a certain point. Consequently there is a force which opposes the actual contact of bodies; a force which increases inversely as some power or function of the distance, and which no power whatever is capable of overcoming. Boscovich has demonstrated, that a body in motion communicates part of its motion to another body before it actually reaches it. Hence we may conclude that, as far as we know, there is no such thing as actual contact in nature, and that bodies of course always act upon each other at a distance. Even impulsion, therefore, or pressure, is an instance of bodies acting on each other at a distance, and therefore is no better explanation of attraction than the supposition that it is an inherent power. We must therefore be satisfied with considering attraction as an unknown power, by which all bodies are urged towards each other. It is a power which acts constantly and uniformly in all times and places, and which is always diminishing the distance between bodies, unless when they are prevented from approaching each other by some other force equally powerful.

Of two kinds.

6. The change which attraction produces on bodies is a diminution of their distance. Now the distances of bodies from each other are of two kinds, either too small to be perceived by our senses, or great enough to be easily perceived and estimated. In the first case,

e change of distance produced by attraction must be sensible, in the second case it must be visible. Hence e attractions of bodies, as far as regards us, naturally vide themselves into two classes. 1. Those which ct at sensible distances. 2. Those which act at insen- ble distances. The first class obviously applies to odies in masses of sensible magnitude; the second class ust be confined to the particles of bodies, because ey alone are at insensible distances from each other.

1. At sensible distances.

7. It has been demonstrated, that the intensity of the rst class of attractions varies with the mass and the istance of the attracting bodies. It increases with the ass of these bodies, but diminishes as the distance etween them increases. Hence we see that in this lass of attractions every particle of the attracting bo- ies acts, since the sum of the attracting force is al- vays proportional to the number of particles in the at- racting bodies. Why it diminishes as the distance in- reases, it is impossible to say; but the fact is certain, nd is almost incompatible with the supposition of im- ulsion as the cause of attraction. The rate of varia- ion has been demonstrated to be inversely as the square f the distance in all cases of attraction belonging to he first class.

8. The attractions belonging to the first class must e as numerous as there are bodies situated at sensible istances; but it has been ascertained that they may be ll reduced to three different kinds; namely, 1. Gravi- ation; 2. Electricity; 3. Magnetism. The first of hese has been shewn by Newton to belong to all mat- er as far as we have an opportunity of examining, and herefore to be universal The other two are partial, being confined to certain sets of bodies, while the rest

Book III. of matter is destitute of them; for it is well known that all bodies are not electric, and that scarcely any bodies are magnetic, except iron, cobalt, nickel, and perhaps manganese.

The intensity of these three attractions increases as the mass of the attracting bodies, and diminishes as the square of the distance increases. The first extends to the greatest distance at which bodies are known to be separated from each other. How far electricity extends has not been ascertained; but magnetism extends at least as far as the semidiameter of the earth. All bodies possess gravity; but it has been supposed that the other two attractions are confined to two or three subtile fluids, which constitute a part of all those bodies which exhibit the attractions of electricity or magnetism. This may be so; but it has not and scarcely can be demonstrated.

9. The absolute force of these attractions in given bodies can only be measured by the force necessary to counteract the effect of these attractions, or by the space which given bodies, acted on merely by these attractions, traverse in a given time. If we compare the different bodies acted on by gravitation, we shall find that the absolute force of their gravitation towards each other is in all cases the same, provided their distances from each other and their mass be the same; but this is by no means the case with electrical and magnetic bodies. In them the forces by which they are attracted towards each other, called electricity and magnetism, are exceedingly various, even when the mass and the distance are the same. Sometimes these forces disappear almost entirely; at other times they are exceedingly intense. Gravity therefore is a force inherent in

bodies ; electricity and magnetism not so ; a circumstance which renders the opinion of their depending upon peculiar fluids exceedingly probable. If we compare the absolute force of these three powers with each other, it would appear that the intensity of the two last, every thing else being equal, is greater than that of the first ; but their relative intensity cannot be compared, and is therefore unknown. Hence it follows that these different attractions, though they follow the same laws of variation, are not the same in kind.

2. Affinity

10. The attractions between bodies at insensible distances, and which of course are confined to the particles of matter, have been distinguished by the name of *affinity*, while the term *attraction* has been more commonly confined to cases of sensible distance. Now the particles of matter are of two kinds, either *homogeneous* or *heterogeneous*. By homogeneous particles, I mean particles which compose the same body ; thus all particles of iron are homogeneous. By heterogeneous particles are meant those which compose different bodies ; thus a particle of iron and a particle of lead are heterogeneous.

Homogeneous affinity urges the homogeneous particles towards each other, and keeps them at insensible distances from each other ; and consequently is the cause why bodies almost always exist united together, so as to constitute masses of sensible magnitude. This affinity is usually denoted by the term *cohesion*, and sometimes by *adhesion* when the surfaces of bodies are only referred to. Homogeneous affinity is nearly universal ; as far as is known, caloric and light only are destitute of it.

Heterogeneous affinity urges heterogeneous particles towards each other, and keeps them at insensible distances from each other, and of course is the cause of the formation of new integrant particles composed of a certain number of heterogeneous particles. These new integrant particles afterwards unite by cohesion, and form masses of compound bodies. Thus an integrant particle of water is composed of particles of hydrogen and oxygen, urged towards each other, and kept at an insensible distance by heterogeneous affinity; and a mass of water is composed of an indefinite number of integrant particles of that fluid, urged towards each other by homogeneous affinity. Heterogeneous affinity is universal, as far as is known; that is to say, there is no body whose particles are not attracted by the particles of some other body; but whether the particles of all bodies have an affinity for the particles of all other bodies, is a point which we have no means of ascertaining. It is, however, exceedingly probable, and has been generally taken for granted; though it is certainly assuming more than even analogy can warrant.

Increases with the mass

11. Affinity, like sensible attraction, varies with the mass and the distance of the attracting bodies. That cohesion varies with the mass, cannot indeed be ascertained; because we have no method of varying the mass without at the same time altering the distance. But in cases of the adhesion of the surfaces of homogeneous bodies, which is undoubtedly an instance of homogeneous affinity, it has been demonstrated, that the force of adhesion increases with the surface, that is to say, with the mass; for the number of adhering particles must increase with the surface.

That heterogeneous affinity increases with the mass, has been observed long ago in particular instances, and as been lately demonstrated by Berthollet to hold in very case; thus a given portion of water is retained ore obstinately by a large quantity of sulphuric acid han by a small quantity. Oxygen is more easily abtracted from those oxides which are oxidated to a ma-imum, than from those which are oxidated to a mini-num; that is to say, that a large mass of metal retains given quantity of oxygen more violently than a small nass. Lime deprives potass of only a portion of its car-onic acid, and sulphuric acid deprives phosphoric acid f only a portion of the lime with which it is united in hosphat of lime. In these, and many other instances hat might be enumerated, a small portion of one body s retained by a given quantity of another more strongly han a large quantity. And Berthollet has shewn, that in ll cases a large quantity of a body is capable of abstract-ng a portion of another from a small portion of a third; ow weak soever the affinity between the first and se-ond of these bodies is, and how strong soever the affi-ity between the second and the third. Thus when qual quantities of the following bodies were boiled ogether,

1.	Sulphat of potass Potass	4.	Oxalat of lime Potass
2.	Sulphat of potass Soda	5.	Phosphat of lime Potass
3.	Sulphat of potass Lime	6.	Carbonat of lime Potass

he uncombined base abstracted part of the acid from he base with which it was previously combined; hough in every one of these instances it was retained y that base by an affinity considered as stronger. The ame division of the base took place when equal quantities of oxalat of lime and nitric acid were boiled together.

Inversely as the distance.

That the force of affinity increases as the distance diminishes, and the contrary, is obvious; for it becomes insensible whenever the distance is sensible, and on the other hand, becomes exceedingly great when the distance is exceedingly diminished. But the particular rate which this variation follows is still unknown, as we have no method of measuring either the distances at which it acts, or its relative intensity at these distances. Some have supposed that it follows a greater ratio than $\frac{1}{d^2}$, and that it diminishes at least as $\frac{1}{d^3}$, if not at some greater rate. But their reasoning has depended altogether upon the supposition that the particles of bodies united by affinity are in actual contact and loses its force, or at least a considerable part of it, if we suppose, what seems actually to be the case, that even then these particles are at a distance. Others have supposed that the intensity of affinity varies inversely as the square of the distance, resting chiefly upon the analogy of sensible attraction which follows that law. This is certainly a kind of presumption in favour of the opinion, and it must be allowed that no sufficient arguments have been advanced to prove that this law is incompatible with the phenomena of affinity. But neither, on the other hand, have any thing like proofs been advanced to show that affinity actually varies according to that law. The truth is, that at present the subject is beyond the reach of philosophy. We must therefore suspend our judgment altogether till future discoveries put it in our power to determine the point.

12. Affinity then agrees with sensible attraction in

ery point which it has been hitherto possible to de- rmine. Like sensible attraction, it increases with the ass, and diminishes as the distance augments; conse- ently we must conclude that attraction, whether it e sensible or insensible, is in all cases the same kind of rce, and regulated by precisely the same general laws.

We have seen that sensible attraction, though in all ses the *same kind* of force, is not always the *very same* rce; for though the mass and the distance of two dies be equal, the absolute force by which they are tracted towards each other by gravitation is not equal the force by which they are attracted towards each her by magnetism. The forces of sensible attraction e three in number, namely, gravitation, magnetism, d electricity; the first is always the same when the ass and distance are the same, but the two last vary even en the mass and distance continue unaltered.

Affinity varies in intensity,

The forces of affinity, though also the same in kind, e still more numerous than those of sensible attrac- n; for instead of three, they amount to as many as ere are heterogeneous bodies. The rate, indeed, at ich they vary when the distance of the attracting dies increases or diminishes, is probably the same in , and so is also their variation as far as it regards the ss. But even when both of these circumstances, as as we can estimate them, are the same, the affinity two bodies for a third is not the same. Thus barytes a stronger affinity for sulphuric acid than potass has: if equal quantities of each be mixed with a small rtion of sulphuric acid, the barytes seizes a much ater proportion of the acid than the potass does. is difference in intensity extends to particles of all dies; for there are scarcely any two bodies whose particles have precisely the same affinity for a third, and scarcely any two bodies, the particles of each of which cohere together with exactly the same force.

It is this difference in intensity which constitutes the most important characteristic mark of affinity, and which explains the different decompositions and changes which one body occasions in others.

Thus it appears at first sight, that there are as many different affinities as there are bodies; and that affinity, instead of being one force, like gravitation, which is always the same when the circumstances are the same, consists of a variety of different forces, regulated, indeed, by the same kind of laws, but all of them different from each other. These affinities do not vary like magnetism and electricity, though the mass continues the same, but are always of equal intensity when other circumstances are equal. Hence it is reasonable to conclude that these affinities cannot, like magnetism and electricity, depend upon peculiar fluids, the quantity of which may vary, but that they are permanent forces, inherent in every atom of the attracting bodies.

13. It is very possible that this variation of intensity, which forms so remarkable a distinction between affinity and gravitation, may be only apparent and not real. For even in gravitation the intensity varies with the distance and the mass, and the same variation holds in affinity But as the attraction of affinity acts upon bodies situated at insensible distances from each other, it is evident that, strictly speaking, we have no means of ascertaining that distance, and consequently that it may vary without our discovering the variation. But every such variation in distance must occasion a corresponding variation in the intensity of the attracting force. I

nay be then that barytes attracts sulphuric acid with reater intensity than potass, because the particles of arytes, when they act upon the acid, are at a smaller istance from it than the particles of the potass are.

Owing perhaps to the figure of the particles.

But it may be asked, Why, if barytes, potass, and ulphuric acid, are all mixed together in water, the paricles of potass do not approach as near the acid as hose of the barytes, since they are both at liberty to ct? To this it may be answered, That in all probability hey do approach each of them to the same *apparent* istance (if the expression be allowable), but that, notvithstanding, their *real* distance may continue different. The particles of bodies, how minute soever we suppose hem to be, cannot be destitute of magnitude. They must have a certain length, breadth, and thickness, and herefore must always possess some particular figure or ther. These particles, indeed, are a great deal too ninute for us to detect their shape; but still it is cerain that they must have some shape. Now it is very onceivable that the particles of every particular body may have a shape peculiar to themselves, and differing rom the shape of the particles of every other body. Thus the particles of sulphuric acid may have one hape, those of barytes another, and those of potass a hird.

But if the particles of bodies have length, breadth, nd thickness, we cannot avoid conceiving them as omposed of an indeterminate number of still more ninute particles or atoms. Now the affinity of two ntegrant particles for each other must be the sum of he attractions of all the atoms in each of these particles or all the atoms in the other: But the sum of these ttractions must depend upon the number of attracting atoms, and upon the distance of these atoms from each other respectively; and this distance must depend upon the figure of the particles. For it is obvious, that if two particles, one of which is a tetrahedron and the other a cube, and which contain the same number of atoms, be placed at the same relative distance from a third particle, the sum of the distances of all the atoms of the first particle from all the atoms of the third particle, will be less than the sum of the distances of all the atoms of the second particle from those of the third. Consequently, in this case, though the apparent distance of the particles be the same, their real distance is different; and of course the cube will attract the third particle more strongly than the tetrahedron; that is, it will have a greater affinity for it than the tetrahedron.

But if the particles of bodies differ from each other in figure, they may differ also in density and in size; and this must also alter the absolute force of affinity, even when the distances and the figure of the attracting particles are the same. The first of these two circumstances indeed may be considered as a difference in the mass of the attracting bodies, and therefore may be detected by the weight of the aggregate; but the second, though also no less a variation in the mass, cannot be detected by any such method, though its effect upon the strength of affinity may be very considerable

There is no doubt that, upon the supposition that such differences in the figure, density, and size of the attracting particles, really exist, and it is in the highest degree probable that they do exist, the variation in intensity which characterises chemical affinity may be accounted for, without supposing that the intensity of ffinity as a force inherent in the ultimate particles or toms of bodies is really different. The same thing ay be applied to electricity and magnetism. It is certainly possible, therefore, that attraction, both sensible nd insensible, may not only vary at the same rate, and ccording to the same laws, but be absolutely the same orce inherent in the atoms of matter, modified merely y the number and situation of the attracting atoms. This is certainly possible; and it must be allowed that t corresponds well with those notions of the simplicity f Nature in which we are accustomed to indulge ourselves. But the truth is, that we are by no means good udges of the simplicity of Nature; we have but an imperfect glimpse here and there through the veil with which her operations are covered; and from the few oints which we see, we are constantly forming conjectures concerning the whole of the machinery by which hese operations are carried on. Superior beings smile t our theories as we smile at the reasonings of an infant; and were the veil which conceals the machine rom our view to be suddenly withdrawn, we ourselves, n all probability, would be equally astonished and confounded at the wide difference between our theories and onjectures, and the real powers by which the machinery of the universe is moved. Let us not therefore be oo precipitate in drawing general conclusions; but let s rather wait with patience till future discoveries enable us to advance farther; and satisfy ourselves in the mean time with arranging those laws of affinity which ave been ascertained, without deciding whether it be he same force with gravitation, or a different one.

May be the same with gravitation.

14. The characteristic marks of affinity may be reluced to the three following:

Its characters.

I. It acts only at insensible distances, and of course affects only the particles of bodies.

II. This force is always the same in the same particles, but it is different in different particles.

III. This difference is modified considerably by the mass. Thus though A have a greater affinity for C than B has, if the mass of B be considerably increased while that of A remains unchanged, B becomes capable of taking a part of C from A.

But it will be necessary to consider the affinity of homogeneous and heterogeneous bodies more particularly. This will be the subject of the two following Chapters.

CHAP II.

OF HOMOGENEOUS AFFINITY.

WE never find the particles of bodies in a separate tate: they are either combined with the particles of ther bodies, or with each other, forming masses of reater or smaller magnitude. This last union is the ffect of homogeneous affinity; which has been already efined to mean that force which unites homogeneous articles to each other. Now in homogeneous affinity ere are two things which claim our attention: The rst is the force itself by which the particles are kept nited; the second is the form which the particles hus united are known to assume. The force is distinuished by the title of *cohesion;* and the form of the ass, when regular, has received the name of *crystal.* hese two topics shall form the subject of the two folowing Sections, under the titles of *Cohesion* and *Crytallization.*

SECT. I.

OF COHESION.

THE force called *cohesion* is inherent in all the particles of all bodies, if we except caloric and light: For all bodies except these constantly exist in masses composed of an indefinite number of particles united together. This force possesses all the characters of affinity.

1. It acts only at insensible distances; for whenever we remove the particles of a body to a perceptible distance from each other, they cease to cohere altogether.

Cohesion varies in different bodies.

2. Cohesion is exceedingly various in different bodies; though in the same body, if other things be equal, it is always the same. Thus an iron rod is composed of particles of iron cohering so strongly, that it requires an enormous force to separate them. A smaller force is necessary to overcome the cohesion of lead, and a still smaller to separate the particles of chalk from each other. In short, there are scarcely two bodies whose particles cohere with the same force. The force of cohesion in solid bodies is measured by the weight necessary to break them, or rather to pull them asunder. Thus if a rod of glass be suspended in a perpendicular direction, and weights be attached to its lower extremity till the rod is broken by them, the weight attached to the rod just before it broke is the measure of the cohesive force of the rod. We are indebted to Muschenbroeck for the most complete set of experiments hither-

› made upon the cohesive force of solid bodies. Sick- ıgen has also examined the cohesion of several of the ıetals with much accuracy. The results of the la- ɔurs of the first of these philosophers may be seen in ıe following TABLE *:

I. METALS.

Steel, bar	135,000
Iron, bar	74,500
Iron, cast	50,100
Copper, cast	28,600
Silver, cast	41,500
Gold, cast	22,000
Tin, cast	4,440
Bismuth	2,900
Zinc	2,600
Antimony	1,000
Lead, cast	860

II. ALLOYS.

Gold 2 parts, silver 1 part	28,000
Gold 5, copper 1	50,000
Silver 5, copper 1	48,500
Silver 4, tin 1	41,000
Copper 6, tin 1	55,000
Brass	51,000
Tin 3, lead 1	10,200
Tin 8, zinc 1	10,000
Tin 4, antimony 1	12,000
Lead 8, zinc 1	4,500
Tin 4, lead 1, zinc 1	13,000

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* In this Table the numbers denote the pounds avoirdupois which are ıst sufficient to tear asunder a rod of each of the bodies whose base is n inch square.

III. Woods.

Locust tree	20,100
Jujeb	18,500
Beech, oak	17,300
Orange	15,500
Alder	13,900
Elm	13,200
Mulberry	12,500
Willow	12,500
Ash	12,000
Plum	11,800
Elder	10,000
Pomegranate	9,750
Lemon	9,250
Tamarind	8,750
Fir	8,330
Walnut	8,130
Pitch pine	7,656
Quince	6,750
Cypress	6,000
Poplar	5,500
Cedar	4,880

IV. Bones.

Ivory	16,270
Bone	15,250
Horn	8,750
Whalebone	7,500
Tooth of sea calf	4,075

Explained by Boscovich.

3. The nature of cohesion has been more happily explained by Boscovich than by any other philosopher. Indeed it forms the most beautiful and satisfactory part

his theory. According to him, the particles of bo- es cohere together when they are placed in the limit repulsion and attraction. Two particles, when si- ated at a certain distance from each other, repel each ther mutually; this repulsion gradually diminishes as e distance between the particles increases, till at last hen the distance reaches a certain magnitude, the re- ulsion ceases altogether. If the distance be increased ver so little, the particles now, instead of repelling, at- ract each other; and this attraction increases with the istance, till at last it reaches its maximum. From his point it gradually diminishes, till at last, when he particles have acquired a certain distance, it va- ishes altogether. If the distance be increased ever little beyond that distance, the particles now again epel each other. He supposes that the insensible di- tance between two particles is divided into an indefi- ite number of portions of alternate repulsions and at- ractions.

Let the line AH (fig. 11.) represent the insensible istance between two particles; and let the ordinates of he curve I Q q q' q'' represent the attracting and repel- ing forces of the two particles as the second moves a- ong the line AB while the first remains in the point A. The ordinates of the curves situated above the line AH represent repulsive forces, and those below the ine represent attracting forces. The points B, C, D, E, F, G, H, where the curve cuts the axis, represent he limits between repulsion and attraction. While the econd particle is in any part of the line AB it is epelled: the repulsion increases as the particle ap- roaches A, and at the point A it is infinite, because the ine A a is to be considered as an asymptote to the

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curve. At the point B the second particle is neither repelled nor attracted. In every part of the line BC it is attracted; and the attraction is a maximum at P, because there the ordinate PQ is a maximum At the point C it is neither attracted nor repelled. In every part of CD it is repelled; in D it is neither attracted nor repelled; in DE it is attracted, and so on.

Now the points B, D, F, and H, are called by Boscovich limits of cohesion, because particles placed in these points remain unaltered, and even resist any force which endeavours to displace them. If they are driven nearer each other, they are again repelled to their former limit: on the other hand if they are driven to a greater distance, they are again attracted to their former situation.

Boscovich supposes, that in all cases of cohesion the particles of the cohering body are so situated as to be in these limits of cohesion with respect to each other. According to this very ingenious theory, cohesion is not, properly speaking, a force, bnt the interval between two forces. And even if we were to modify the theory a little, still we must consider cohesion as the balancing of two opposite forces, either of which becomes prevalent according as the cohering particles are urged nearer each other or forced to a greater distance. Consequently, if we were to speak with precision, *cohesion* is not itself a force, but the absence of a force. What has been hitherto called the *force of cohesion*, is the attraction which prevents the cohering particles from separating from each other, and which begins to act; or, more precisely, which becomes prevalent when the particles are urged to a greater distance from each other.

4. Boscovich has shewn, in a very satisfactory man- r, how all the varieties of cohesion may be produced the differences in the size, figure, and density, of the hering particles *. It deserves attention, that in most ses the cohesive force of simple bodies is greater than at of compound bodies. To this indeed there are a eat number of exceptions, but the observation holds a variety of instances. All the metals cohere very ongly ; the diamond probably coheres with no less rce, if we can judge from its hardness; and the cohe- on of sulphur is also very considerable. Thus if we cept phosphorus, all the simple substances are re- arkable for cohesion. Those of them which are in e state of elastic fluids must be excluded altogether; cause in that particular state the particles, instead of ing in the limit of cohesion, are actually repelled. In e earths, too, such of them at least as are found cry- llized in a state of purity, the cohesion is very strong. hus the sapphire or crystallized alumina, and rock ystal or crystallized silica, are always very hard, and hibit a much stronger cohesion than limestone, or agnesian stones, which are composed of heterogeneous dies. This remark, however, by no means applies the metals; for in them the cohesion is very often creased considerably by alloying them together. Thus e cohesion of copper is doubled by alloying it with e-sixth of its weight of tin, though the cohesion of e tin is scarcely one-sixth of that of the copper.

The cohesion of metals is greatly increased by for- ng them, and by drawing them out into wire. By is last operation gold, silver, and brass, have their

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* See his *Theoria Philosophiæ Naturalis*, Part iii. Sect. 406, p. 185.

cohesion nearly tripled; copper and iron more than doubled.

5. There are three states in which bodies exist exceedingly distinct from each other; the state of solids, of liquids, and of elastic fluids. In the two first states the particles cohere with more or less force; but the cohesion produces in them very different effects. In the first it prevents all relative motion among the particles themselves; in the second, this relative motion is left at full liberty. Hence in solid bodies the motion of one particle is followed by the motion of the whole mass; or if that is impossible, the cohesion is destroyed altogether. In liquids, on the contrary, the motion of one particle is not necessarily followed by that of the rest, neither does that motion destroy the cohesion. Boscovich has shewn, that solidity and fluidity are the consequence of the figure of the cohering particles. If that figure is such that the particles may change their position without altering their relative distances, the consequence must be fluidity; because in that case there is nothing to oppose the motion of any individual particle. This happens when the particles are spherical; but if the figure be such that the particles cannot change their position without altering their relative distances, the bodies which they compose must be solids, because all relative motion of an individual particle is opposed by the attractions and repulsions of all the surrounding particles; for every motion must bring the particle out of the former limit of cohesion. This happens when the particles have the figure of parallelopipeds, or any other figure except that of spheres.

This explanation is exceedingly ingenious; but it would not be an easy task to explain by means of it all

Chap. II.

e phenomena of solidity and fluidity. How comes it, r instance, that the addition of a certain dose of calo- : renders a body fluid which was before solid? If it answered, that it acts by combining with the parti- :s of the solid in such a manner as to render them herical; how comes it, in that case, that gold and atinum, metals which are ductile and malleable, pro- :rties which indicate a kind of approach to fluidity, ıd of course to sphericity, in the particles of these etals—how comes it that they require so much more .loric to render them fluid than bismuth or sulphur, hich are altogether brittle? We must rather consider uidity as a kind of solution in caloric, analogous to the ›lution of salts in water. But this explanation, tho' would do very well in many instances, would lead ; in others to difficulties as great as those which we 'e endeavouring to avoid.

The cohesion of liquids is often very considerable. .ccording to Sir Isaac Newton, it is nearly propor- onal to the density of the liquid. This holds pretty :curately in several instances: but it is not easy to ;certain the cohesion of a liquid with precision, because ıe particles slide upon each other, and the column of ıe liquid, whose cohesion we are measuring, always :comes smaller and smaller, till at last it consists only f a very small number of particles.

Viscid bodies have particles approaching to a sphe- ical form; but deviating from it so far as to occasion certain resistance to the relative motion of the par- cles.

Solid bodies are of two kinds: they may either re- st all change of distance in their particles so strongly s not to be capable of compression or dilatation with-

Book III. out a breach of cohesion; or they may admit of both to a certain degree with facility. The first of these constitutes hardness; the second constitutes softness, if the particles retain their new situation, or elasticity if they return again to their old position when the external force is removed*. Ductility and malleability depend upon the same state as softness, only the particles require a greater force to make them change their situation and assume a new one.

Solution.

6. When a solid body is plunged into a liquid, if the particles of the liquid attract those of the solid with a greater force than these last particles attract each other, they are gradually carried off by the fluid, and combine with its particles, that is to say, the solid is gradually dissolved. Thus sugar is disolved by water, and sulphur by oil. The particles of the solid thus dissolved are each of them surrounded and combined with a certain number of the particles of the liquid. Hence they must be arranged in the liquid in regular order, and at regular distances from each other. The greater number of particles thus dissolved by the liquid, the smaller is the affinity by which each of them is retained, because it is surrounded by a smaller number of particles of the liquid. But the greater must be the force with which these particles are attracted towards each other, and of course tend to form the solid again by cohesion; because the greater the number of the particles of the solid dissolved in the fluid, the nearer are they to each other.

Thus it appears that the affinity between the fluid and solid diminishes with the quantity dissolved; but that the tendency to cohesion increases with that quan-

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* Boscovich, *Theoria Naturalis*, p. 199.

r. Consequently if the solution be supposed to go these two opposite forces must at last balance one ther. And whenever that happens, the liquid can solve no more of the solid. If it did, the particles he solid would in part cohere, and form a new porn of the solid again. Whenever this happens, the id is said to be *saturated*. The saturation of a fluid n does not mean that its affinity for the solid is saied, but that it is not greater than the tendency of combined particles to cohere. Now, when a liquid saturated with a solid, if by any means we can abact part of that liquid, the cohesive force of the parles of the solid must gain the superiority; and the nsequence will be, that they will unite and form solid dies anew, till their number be so much diminished, t their mutual attraction is again counterbalanced the affinity of the liquid. Hence the reason that poration occasions the crystallization of those bodies ich are held in solution by liquids.

7. These different solid bodies differ excessively from h other in their tendency to cohesion; and this diffeice can only be ascertained by experiment. Thus the dency to cohesion, and the force of cohesion in silica, so strong, that when it has been precipitated from a ution by evaporation, it cannot be dissolved again in same liquid.

This tendency to cohesion, and the consequent insoility of the compound, produce many of the most portant phenomena of chemistry, as they occasion various precipitations and decompositions which so en take place when different substances are mixed gether. But this subject belongs more properly to next Chapter, in which it will be necessary to point out the effect of cohesion as an antagonist to heterogenous affinity. Let us proceed, therefore, to consider the forms which bodies assume when their particles have full liberty to unite themselves by cohesion.

SECT. II.

OF CRYSTALLIZATION.

Crystals formed by

THE word *crystal* (κρυσταλλος), originally signified *ice*; but it was afterwards applied by the ancients to crystallized silica, or *rock crystal*; because, as Pliny informs us, they considered that body as nothing else than water congealed by the action of cold. Chemists afterwards applied the word to all transparent bodies of a regular shape; and at present it is employed to denote in general the regular figures which bodies assume when their particles have full liberty to combine according to the laws of cohesion. Now there are three ways by which they may be put into that situation, namely, solution, suspension, and fusion.

Solution,

1. Solution is the common method of crystallizing salts. They are dissolved in water: the water is slowly evaporated, the saline particles gradually approach each other, combine together, and form small crystals; which become constantly larger by the addition of other particles till at last they fall by their gravity to the bottom of the vessel. It ought to be remarked, however, that there are two kinds of solution, each of which pre-

ents different phenomena of crystallization. Some salts issolve in very small proportions in cold water, but are ery soluble in hot water; that is to say water at the onmon temperature has little effect upon them. but ater combined with caloric dissolves them readily. Vhen hot water saturated with any of these salts cools, becomes incapable of holding them in solution: the onsequence of which is, that the saline particles graually approach each other and crystallize. Sulphat of oda is a salt of this kind. To crystallize such salts othing more is necessary than to saturate hot water ith them, and set it by to cool. But were we to atempt to crystallize them by evaporating the hot water, e should not succeed; nothing would be procured but shapeless mass. Many of the salts which follow this w of crystallization combine with a great deal of war; or, which is the same thing, many crystals formed this manner contain a great deal of water of crystalzation.

There are other salts again which are nearly equally luble in hot and cold water; common salt for instance. is evident that such salts cannot be crystallized by oling; but they crystallize very well by evaporating eir solution while hot. These salts generally contain at little water of crystallization.

Suspension,

2. It appears, too, that some substances are capable f assuming a crystalline form merely by having their articles suspended in water, without any regular soluon; at least it is not easy, on any other supposition, explain the crystallizations of carbonat of lime somemes deposited by waters that run over quantities of at mineral.

Fusion.

3. There are many substances, however, neither soluble in water, nor capable of being so minutely divide as to continue long suspended in that fluid; and which notwithstanding, are capable of assuming a crystallin form. This is the case with the metals, with glass, an some other bodies. The method employed to crysta lize them is *fusion*, which is a solution by means of ca loric. By this method the particles are separated fro one another; and if the cooling goes on gradually, the are at liberty to arrange themselves in regular crystals.

There are several bodies which it has been impossib hitherto to reduce to a regular crystallized form, eithe by these or any other method, owing chiefly, no doub to our ignorance of the laws of crystallization; fo many of these bodies are found native in regular crystals. This is the case with carbon and alumina, an many earthy combinations.

Nature of crystallization.

4. The phenomena of crystallization seem to have a tracted but little of the attention of the ancient philosophers. Their theory indeed, that the elements of bodies possess certain regular geometrical figures, ma have been suggested by these phenomena; but we a ignorant of their having made any regular attempt t explain them. The schoolmen ascribed the reqular f gure of crystals to their substantial forms, without givi themselves much trouble about explaining the meani of the term. This notion was attacked by Boyle; wh proved, that crystals are formed by the mere aggregation of particles*. But it still remained to explai

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* *Treatise on the Origin of Forms and Qualities.*

hy that aggregation took place? and why the particles nited in such a manner as to form regular figures?

The aggregation is evidently the consequence of that tractive force which has been examined in the last Secon. But to explain the cause of the regular figures is a ore difficult task. Newton has remarked, that the parcles of bodies while in a state of solution, are arranged the solvent in regular order and at regular distances; e consequence of which must be, that when the rce of cohesion becomes sufficiently strong to sepaate them from the solvent, they will naturally combine groups, composed of those particles which are nearest ach other. Now all the particles of the same body ust be supposed to have the same figure; and the ombination of a determinate number of similar bodies ust produce similar figures. Hauy has made it exeedingly probable that these integrant particles always ombine in the same body in the same way, that is to ay, that the same faces, or the same edges, always atach themselves together; but that these differ in diffeent crystals. This can scarcely be accounted for, without supposing that the particles of bodies are endowed with a certain polarity which makes them attract one art of another particle and repel the other parts. This olarity would explain the regularity of crystallization; ut it is itself inexplicable.

5. It has been observed, that those salts which crystallize upon cooling, do not assume a crystalline form so readily if they are allowed to cool in close vessels. If a saturated solution of sulphat of soda, for instance, in hot water, be put into a phial, corked up closely, and allowed to cool without being moved, no crystals are

formed at all; but the moment the glass is opened, the salt crystallizes with such rapidity that the whole of the solution in a manner becomes solid. This phenomenon has been explained by supposing that there is an affinity between the salt and caloric, and that while the caloric continues combined with it the salt does not crystallize; that the caloric does not leave the salt so readily when external air is not admitted, as glass receives it very slowly and parts with it very slowly. In short, the atmospherical air seems to be the agent employed to carry off the caloric; a task for which it is remarkably well fitted, on account of the change of density which it undergoes by every addition of caloric. This is confirmed by the quantity of caloric which always makes its appearance during these sudden crystallizations. This explanation might be put to the test of experiment, by putting two solutions of sulphat of soda in hot water in two similar vessels; one of glass, the other of metal, and both closed in the same manner. If the salt contained in the metallic vessel crystallized, which ought to be the case on account of the great conducting power of metals, while that in the glass vessel remained liquid, this would be a confirmation of the theory, amounting almost to demonstration. On the contrary, if both solutions remained liquid, it would be a proof that the phenomenon was still incompletely understood.

Not only salts but water itself, which commonly crystallizes at 32°, may be made to exhibit the same phenomenon: it may be cooled much lower than 32° without freezing. This, as Dr Black has completely proved, depends entirely upon the retention of caloric.

6. If the figure of crystals depends upon the figure f their integrant particles, and upon the manner in hich they combine, it is reasonable to suppose that e same particles, when at full liberty, will always ombine in the same way, and consequently that the rystals of every particular body will be always the same. othing at first sight can appear farther from the uth than this. The different forms which the crystals f the same body assume are often very numerous, and xceedingly different from each other. Carbonat of me, for instance, has been observed crystallized in no wer than forty different forms, fluat of lime in eight ifferent forms, and sulphat of lime in nearly an equal umber.

All crystals have a primitive form.

But this inconsistency is not so great as might at rst sight appear. Romé de Lisle has shown that every ody susceptible of crystallization has a particular form hich it most frequently assumes, or at least to which most frequently approaches. Bergman has demonstrated, that this primitive form, as Hauy has called it, ery often lies concealed in those very crystals which ppear to deviate farthest from it. And Hauy has demonstrated, that all crystals either have this primitive orm, or at least contain it as a nucleus within them; or it may be extracted out of all of them by a skilful echanical division.

Happening to take up a hexangular prism of calcareous spar, or carbonat of lime, which had been detached rom a group of the same kind of crystals, he observed hat a small portion of the crystal was wanting, and that he fracture presented a very smooth surface. Let *a b c d* *f g h* (fig. 12.) be the crystal; the fracture lay obliquely as the trapezium *p s u t*, and made an angle of 135°, both with the remainder of the base *a b c s p h* and with *t u e f*, the remainder of the side *i n e f* Observing that the segment *p s u t i n* thus cut off had for its vertex *i n*, one of the edges of the base *a b c n i h* of the prism, he attempted to detach a similar segment in the part to which the next edge *c n* belonged; employed for that purpose the blade of a knife, directed in the same degree of obliquity as the trapezium *p s u t*, and assisted by the strokes of a hammer. He could not succeed: But upon making the attempt upon the next edge *b c*, he detached another segment, precisely similar to the first, and which had for its vertex the edge *b c*. He could produce no effect on the next edge *a h*; but from the next following, *a h*, he cut a segment similar to the other two. The sixth edge likewise proved refractory. He then went to the other base of the prism *d e f g h r*, and found, that the edges which admitted sections similar to the preceding ones were not the edges *e f*, *d r*, *g k*, corresponding with those which had been found divisible at the opposite base, but the intermediate edges *d e*, *k r*, *g f*. The trapezium *l q y v* represents the section of the segment which had *k r* for its vertex. This section was evidently parallel to the section *p s u t*; and the other four sections were also parallel two and two. These sections were, without doubt, the natural joinings of the layers of the crystal. And he easily succeeded in making others parallel to them, without its being possible for him to divide the crystal in any other direction. In this manner he detached layer after layer, approaching always nearer and nearer the axis of the prism, till at last the bases disappeared altogether, and the prism was converted into a solid OX (fig. 13.), terminated by twelve pentagons, parallel two and two; of which those at the extremities, that is to say, ASRIO, GEDO, BAODC at one end, and FKNPQ, MNPXU, ZQPXY at the other, were the results of mechanical division, and had their common vertices O, P situated at the entrance of the bases of the original prism. The six lateral pentagons RSUXY, ZYRIG, &c. were the remains of the six sides of the original prism.

By continuing sections parallel to the former ones, the lateral pentagons diminished in length; and at last the points R, G coinciding with the points Y, Z, the points S, R with the points U, Y, &c. there remained nothing of the lateral pentagons but the triangles YIZ, UXY, &c. (fig. 14.). By continuing the same sections, these triangles at last disappeared, and the prism was converted into the rhomboid *a e* (fig. 15.).

So unexpected a result induced him to make the same attempt upon more of these crystals; and he found that all of them could be reduced to similar rhomboids. He found also, that the crystals of other substances could be reduced in the same manner to certain primitive forms; always the same in the same substances, but every substance having its own peculiar form. The primitive form of fluat of lime, for instance, was an octahedron; of sulphat of barytes, a prism with rhomboidal bases; of felspar, an oblique angled parallelopiped, but not rhomboidal; of adamantine spar, a rhomboid, somewhat acute; of blende, a dodecahedron, with rhomboidal sides; and so on.

These primitive forms must depend upon the figure of the integrant particles composing these crystals, and upon the manner in which they combine with each other. Now by continuing the mechanical division of the crystal, by cutting off slices parallel to each of its

Integrant particles of three figures.

faces, we must at last reduce it to so small a size that it shall contain only a single integrant particle. Consequently this ultimate figure of the crystal must be the figure of the integrant particles of which it is composed. The mechanical divison, indeed, cannot be continued so far, but it may be continued till it can be demonstrated that no subsequent division can alter its figure. Consequently it can be continued till the figure which it assumes is similar to that of its integrant particles.

Hauy has found, that the figure of the integrant particles of bodies, as far as experiment has gone, may be reduced to three; namely,

1. The parallelopiped, the simplest of the solids, whose faces are six in number, and parallel two and two.

2. The triangular prism, the simplest of prisms.

3. The tetrahedron, the simplest of pyramids. Even this small number of primitive forms if we consider the almost endless diversity of size, proportion, and density, to which particles of different bodies, though they have the same figure, may still be liable, will be found fully sufficient to account for all the differences in cohesion and heterogeneous affinity without having recourse to different absolute forces.

These integrant particles, when they unite to form the primitive crystals, do not always join together in the same way. Sometimes they unite by their faces, and at other times by their edges, leaving considerable vacuities between each. This explains why integrant particles, though they have the same form, may compose primitive crystals of different figures.

Primitive crystalline forms, six.

Mr Hauy has ascertained, that the primitive forms of crystals are six in number; namely,

1. The parallelopiped, which includes the cube, the rhomboid, and all solids terminated by six faces, parallel two and two.
2. The regular tetrahedron.
3. The octahedron with triangular faces.
4. The six-sided prism.
5. The dodecahedron, terminated by rhombs.
6. The dodecahedron, with isosceles triangular faces.

Each of these may be supposed to occur as the primitive form or the nucleus in a variety of bodies; but those only which are regular, as the cube and the octahedron, have hitherto been found in any considerable number.

Secondary crystals owing to

But bodies, when crystallized, do not always appear in the primitive form; some of them indeed very seldom affect that form; and all of them have a certain latitude and a certain number of forms which they assume occasionally as well as the primitive form. Thus the primitive form of fluat of lime is the octahedron; but that salt is often found crystallized in cubes, in rhomboidal dodecahedrons, and in other forms. All these different forms which a body assumes, the primitive excepted, have been denominated by Hauy *secondary forms*. Now what is the reason of this latitude in crystallizing? why do bodies assume so often these secondary forms?

7. To this it may be answered:

Differences in the composition;

1st, That these secondary forms are sometimes owing to variations in the ingredients which compose the integrant particles of any particular body. Alum, for instance, crystallizes in octahedrons; but when a quantity of alumina is added, it crystallizes in cubes; and when there is an excess of alumina, it does not crystallize at all. If the proportion of alumina varies between that which produces octahedrons and what produces cubic crystals, the crystals become figures with fourteen sides; six of which are parallel to those of the cube and eight to those of the octahedron; and according as the proportions approach nearer to those which form cubes or octahedrons, the crystals assume more or less of the form of cubes or octahedrons. What is still more, if a cubic crystal of alum be put into a solution that would afford octahedral crystals, it passes into an octahedron: and, on the other hand, an octahedral crystal put into a solution that would afford cubic crystals becomes itself a cube *. Now, how difficult a matter it is to proportion the different ingredients with absolute exactness must appear evident to all.

In the solvents; and

2*d*, The secondary forms are sometimes owing to the solvent in which the crystals are formed. Thus if common salt be dissolved in water, and then crystallized, it assumes the form of cubes; but when crystallized in urine, it assumes the form not of cubes, but of regular octahedrons. On the other hand, muriat of ammonia, when crystallized in water, assumes the octahedral form, but in urine it crystallizes in cubes †.

3*d*, But even when the solvent is the same, and the proportion of ingredients, as far as can be ascertained, exactly the same, still there are a variety of secondary forms which usually make their appearance. These secondary forms have been happily explained by the

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* Le Blanc, *Ann. de Chim.* xiv. 149.

† Fourcroy and Vauquelin, Ibid.

theory of crystallization, for which we are indebted to the sagacity of Mr Hauy; a theory which, for its ingenuity, clearness, and importance, must ever rank high, and which must be considered as one of the greatest acquisitions which mineralogy and even chemistry have hitherto attained.

To the different decrements of the crystalline laminæ.

According to this theory, the additional matter which envelopes the primitive nucleus consists of thin slices or layers of particles laid one above another upon the faces of that nucleus; and each layer decreasing in size, in consequence of the abstraction of one or more rows of integrant particles from its edges or angles.

Let us suppose that ABFG (fig 16.) is a cube composed of 729 small cubes: each of its sides will consist of 81 squares, being the external sides of as many cubic particles, which together constitute the cube. Upon ABCD, one of the sides of this cube, let us apply a square lamina, composed of cubes equal to those of which the primitive crystal consists, but which has on each side a row of cubes less than the outermost layer of the primitive cube. It will of course be composed of 49 cubes, 7 on each side; so that its lower base *onfg* (fig. 17.) will fall exactly on the square marked with the same letters in fig. 16.

Above this lamina let us apply a second *lmpu* (fig. 18.), composed of 25 cubes; it will be situated exactly above the square marked with the same letters (fig. 16) Upon this second let us apply a third lamina *vxyz* (fig. 19.), consisting only of 9 cubes; so that its base shall rest upon the letters *vxyz* (fig. 16.) Lastly, on the middle square *r* let us place the small cube *r* (fig. 20.), which will represent the last lamina.

It is evident that by this process a quadrangular pyramid has been formed upon the face ABCD (fig. 16.), the base of which is this face, and the vertex the cube *r* (fig. 20.) By continuing the same operation on the other five sides of the cube, as many similar pyramids will be formed; which will envelope the cube on every side.

It is evident, however, that the sides of these pyramids will not form continued planes, but that, owing to the gradual diminution of the laminæ of the cubes which compose them, these sides will resemble the steps of a stair. We can suppose, however (what must certainly be the case), that the cubes of which the nucleus is formed are exceedingly small, almost imperceptible; that therefore a vast number of laminæ are required to form the pyramids, and consequently that the channels which they form are imperceptible Now DCBE (fig. 21.) being the pyramid resting upon the face ABCD (fig. 16), and CBOG (fig. 21.) the pyramid applied to the next face BCGH (fig. 16.), if we consider that every thing is uniform from E to O (fig. 21.) in the manner in which the edges of the *laminæ of superposition* (as the Abbé Hany calls the laminæ which compose the pyramids) mutually project beyond each other, it will readily be conceived that the face CEB of the first pyramid ought to be exactly in the same plane with the face COB of the adjacent pyramid; and that therefore the two faces together will form one rhomb ECOB. But all the sides of the six pyramids amount to 24 triangles similar to CEB; consequently they will form 12 rhombs, and the figure of the whole crystal will be a dodecahedron.

Thus we see that a body which has the cube for the primitive form of its crystals, may have a dodecahedron or its secondary form. The formation of secondary rystals, by the superposition of laminæ gradually decreasing in size, was first pointed out by Bergman. But Hauy has carried the subject much farther: He has ot only ascertained all the different ways by which hese decrements of the laminæ may take place, but pointed out the method of calculating all the possible variety of secondary forms which can result from a given primitive form; and consequently of ascertaining whether or not any given crystal can be the secondary form of a given species.

The decrements of the laminæ which cover the primitive nucleus in secondary crystals are of four kinds.

These of four kinds.

1. *Decrements on the edges*; that is, on the edges of the slices which correspond with the edges of the primitive nucleus.

2 *Decrements on the angles*; that is to say, parallel to the diagonals of the faces of the primitive nucleus.

3. *Intermediate decrements*; that is to say, parallel to lines situated obliquely between the diagonals and edges of the faces of the primitive nucleus.

4. *Mixed decrements*. In these the superincumbent slices, instead of having only the thickness of one integrant particle, have the thickness of two or more integrant particles; and the decrement, whether parallel to the edges or angles, consists not of the abstraction of one row of particles, but of two or more. Hauy denotes these decrements by fractions, in which the numerator indicates the number of rows of particles which constitutes the decrement, and the denominator represents the thickness of the laminæ. Thus $\frac{2}{3}$ denotes laminæ of the thickness of three integrant particles, decreasing by two rows of particles.

1. Decrements on edges.

An example of the first law of decrement, or of *decrement on the edges*, has been given above in conversion of the cubic nucleus to a rhomboidal dodecahedron In that example the decrement consisted of one row o particles, and it took place on all the edges. But these decrements may be more rapid; instead of one, they may consist of two, three, four, or more rows: and instead of taking place on all the edges, they may be confined to one or two of them, while no decrement at al takes place on the others. Each of these different modifications must produce a different secondary crystal Besides this, the laminæ may cease to be added before they have reached their smallest possible size; the consequence of which must be a different secondary form Thus, in the example given above, if the superpositio of laminæ had ceased before the pyramids were completed, the crystal would have consisted of 18 faces, 6 squares parallel to the faces of the primitive nucleus and 12 hexahedrons parallel to the faces of the secondary dodecahedron. This is the figure of the borat o lime-and-magnesia found at Luneburg.

2. Decrements on the angles.

The second law in which the decrement is on the angles, or parallel to the diagonals of the faces of the primitive nucleus, will be understood from the following example: Let it be proposed to construct around the cube ABGF (fig. 22.), considered as a nucleus, a secondary solid, in which the laminæ of superpositio shall decrease on all sides by single rows of cubes, but in a direction parallel to the diagonals. Let ABCD (fig. 23.), the superior base of the nucleus, be divided into 81 squares, representing the faces of the small cubes of which it is composed. Fig. 24. represents the superior surface of the first lamina of superposition hich must be placed above ABCD (fig. 23.) in such manner, that the points a', b', c', d', (fig. 24.) answer the points a, b, c, d, (fig. 23.) By this disposition, e squares Aa, Bb, Cc, Dd, (fig. 23.) which compose e four outermost rows of squares parallel to the dia- nals AC, BD, remain uncovered. It is evident also, at the borders QV, ON, IL, GF, (fig. 24.) project r one range beyond the borders AB, AD, CD, BC, g. 23.), which is necessary, that the nucleus may be veloped towards these edges.: For if this were not e case, re-entering angles would be formed towards e parts AB, BC, CD, DA of the crystal; which gles appear to be excluded by the laws which determine the formation of simple crystals, or, which comes the same thing, no such angles are ever observed in y crystal. The solid must increase, then, in those rts to which the decrement does not extend. But as is decrement is alone sufficient to determine the form the secondary crystal, we may set aside all the other riations which intervene only in a subsidiary manner, cept when it is wished, as in the present case, to con- uct artificially a solid representation of a crystal, d to exhibit all the details which relate to its struc- re.

The superior face of the second lamina will be A′G′ K′ (fig 25.) It must be placed so that the points , b'', c'', d'' correspond to the points a', b', c', d', (fig. .), which will leave uncovered a second row of cubes each angle, parallel to the diagonals AC and BD. e solid still increases towards the sides. The large ces of the laminæ of superposition, which in fig. 24. ere octagons, in fig. 25. arrive at that of a square; d when they pass that term they decrease on all sides;

so that the next lamina has for its superior face t
square B'M'L'S' (fig. 26.), less by one range in eve
direction than the preceding lamina (fig. 25.) Th
square must be placed so that the points e', f', g',
(fig. 26.) correspond to the points e, f, g, h, (fig. 25
Figures 27, 28, 29, and 30, represent the four lamin
which ought to rise successively above the precedin
the manner of placing them being pointed out by co
responding letters, as was done with respect to t
three first laminæ. The last lamina z' (fig. 31.) is
single cube, which ought to be placed upon the squa
z (fig. 30.)

The laminæ of superposition, thus applied upon t
side ABCD (fig. 23.), evidently produce four fac
which correspond to the points A, B, C, D, and fo
a pyramid. These faces, having been formed by l
minæ, which began by increasing, and afterwards d
creased, must be quadrilaterals of the figure represen
in fig. 32.; in which the inferior angle C is the sa
point with the angle C of the nucleus (fig 22. and 23
and the diagonal LQ represents L'G' of the lami
A'G'L'K' (fig. 25.) And as the number of lami
composing the triangle LQC (fig. 32.) is much smal
than that of the laminæ forming the triangle ZLQ,
is evident that the latter triangle will have a mu
greater height than the former.

The surface, then, of the secondary crystal thus p
duced, must evidently consist of 24 quadrilaterals (
pyramids are raised on the other 5 sides of the prim
cube exactly in the same manner, disposed 3 and 3
round each solid angle of the nucleus. But in con
quence of the decrement by one range, the three q
drilaterals which belong to each solid angle, as C (

2.), will be in the same plane, and will form an equi- teral triangle ZIN (fig 33.) The 24 quadrilaterals, en, will produce 8 equilateral triangles ; and conse- ently the secondary crystal will be a regular octa- edron. This is the structure of the octahedral sul- uret of lead and of muriat of soda.

Third and fourth decrements.

The third law is occasioned by the abstraction of uble, triple, &c. particles. Fig. 34. exhibits an in- ance of the subtractions in question ; and it is seen at the moleculæ which compose the range represent- by that figure are assorted in such a manner as if of o there were formed only one ; so that we need only conceive the crystal composed of parallelopipedons ving their bases equal to the small rectangles *a b c d*, *fg*, *h g i l*, &c. to reduce this case under that of the mmon decrements on the angles.

This particular decrement, as well as the fourth law, ich requires no farther explanation, is uncommon. deed Hauy has only met with mixed decrements in ne metallic crystals.

These different laws of decrement account for all the ferent forms of secondary crystals. But in order to the vast number of secondary forms which may re- t from them, it is necessary to attend to the different difications which result from their acting separately together. These modifications may be reduced to en

Modifications to which these decrements are subject.

1. The decrements take place sometimes on all the es, or all the angles, at once.

2 Sometimes only on certain edges, or certain an- s.

3 Sometimes they are uniform, and consist of one, , or more rows.

4. Sometimes they vary from one edge to another, or from one angle to another.

5. Sometimes decrements on the edges and angles take place at the same time.

6. Sometimes the same edge or angle is subjected successively to different laws of decrement.

7. Sometimes the secondary crystal has faces parallel to those of the primitive nucleus, from the superposition of laminæ not going beyond a certain extent.

Hence Mr Hauy has divided secondary forms into two kinds, namely, *simple* and *compound*. Simple secondary crystals are those which result from a single law of decrement, and which entirely conceal the primitive nucleus. Compound secondary crystals are those which result from several laws of decrement at once, o from a single law which has not reached its limit, an which of course has left in the secondary crystal faces parallel to those of the primitive nucleus.

" If amidst this diversity of laws (observes Mr Hauy) sometimes insulated, sometimes united by combinations more or less complex, the number of the ranges sub tracted were itself extremely variable; for example were these decrements by 12, 20, 30, or 40 ranges, o more, as might absolutely be possible, the multitude o the forms which might exist in each kind of minera would be immense, and exceed what could be imagined But the power which affects the subtractions seems t have a very limited action. These subtractions, for th most part, take place by one or two ranges of mole cules. I have found none which exceeded four range except in a variety of calcareous spar, forming part o the collection of C. Gillet Laumont, the structure o which depends on a decrement by six ranges; so th there exist laws which exceed the decrements by four nges, there is reason to believe that they rarely take lace in nature. Yet, notwithstanding these narrow mits by which the laws of crystallization are circumcribed. I have found, by confining myself to two of e simplest laws, that is to say, those which produce ubtractions by one or two ranges, that calcareous spar susceptible of 2044 different forms: a number which xceeds more than 50 times that of the forms already nown; and if we admit into the combination decreents by three and four ranges, calculation will give ,388,604 possible forms in regard to the same subtance. This number may be still very much augented in consequence of decrements either mixed or termediary.

The striæ remarked on the surface of a multitude of rystals afford a new proof in favour of theory, as they lways have directions parallel to the projecting edges f the laminæ of superposition, which mutually go beond each other, unless they arise from some particular ant of regularity. Not that the inequalities resulting rom the decrements must be always sensible, suppoing the form of the crystals had always that degree of nishing of which it is susceptible; for, on account of e extreme minuteness of the molecules, the surface ould appear of a beautiful polish, and the striæ would lude our senses. There are therefore secondary crytals where they are not at all observed, while they are ery visible in other crystals of the same nature and orm. In the latter case, the action of the causes which roduce crystallization not having fully enjoyed all the onditions necessary for perfecting that so delicate opeation of nature, there have been starts and interruptions in their progress; so that, the law of continuity not having been exactly observed, there have remained on the surface of the crystal vacancies apparent to our eyes. These small deviations are attended with this advantage, that they point out the direction according to which the striæ are arranged in lines on the perfect forms where they escape our organs, and thus contribute to unfold to us the real mechanism of the structure.

The small vacuities which the edges of the laminæ of superposition leave on the surface of even the most perfect secondary crystals, by their re-entering and salient angles, thus afford a satisfactory solution of the difficulty a little before mentioned; which is, that the fragments obtained by division, the external sides of which form part of the faces of the secondary crystal, are not like those drawn from the interior part. For this diversity, which is only apparent, arises from the sides in question being composed of a multitude of small planes, really inclined to one another, but which, on account of their smalness, present the appearance of one plane; so that if the division could reach its utmost bounds, all these fragments would be resolved into molecules similar to each other, and to those situated towards the centre.

The fecundity of the laws on which the variations of crystalline forms depend, is not confined to the producing of a multitude of very different forms with the same molecules. It often happens also, that molecules of different figures arrange themselves in such a manner as gives rise to like polyhedra in different kinds of minerals Thus the dodecahedron with rhombuses for its planes, which we obtained by combining cubic moleules, exists in the granite with a structure composed f small tetrahedra, having isosceles triangular faces ; nd I have found it in sparry fluor *(fluat of lime)*, here there is also an assemblage of tetrahedra, but reular ; that is to say, the faces of which are equilateral riangles. Nay more, it is possible that similar moleules may produce the same crystalline form by diffeent laws of decrement. In short, calculation has conucted me to another result, which appeared to me still ore remarkable, which is, that, in consequence of a imple law of decrement, there may exist a crystal hich externally has a perfect resemblance to the nuleus, that is to say, to a solid that does not arise from ny law of decrement*."

SUCH is a general view of Hauy's theory of crystalization, which has led already to several very imporant discoveries in mineralogy, and may be expected to ead to still more important ones hereafter. The evience for its truth is the complete manner in which it xplains the phenomena, and the exact coincidence of natter of fact in every instance, with the result of calulation. But as it cannot be shewn that the secondary orms are actually crystallized according to the theory, ve must consider it in the light of a mathematical hyothesis ; an hypothesis, however, of very great imortance, because it serves to link together a vast numer of otherwise unconnected facts ; because it enables us to subject all the forms of crystals to calculation ; and because it puts it in our power to ascertain the naure of a body with the utmost certainty, from an accu-

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* *Ann. de Chim.* xvii. 225.

rate examination of the figure of its crystals. Such hypotheses may be considered as the clues which lead us through the otherwise impenetrable mazes of error, and conduct us at last, though after a tedious journey, to the goal of certainty and truth.

CHAP. III.

OF HETEROGENEOUS AFFINITY.

Heterogeneous affinity differs from cohesion merely in being confined to heterogeneous particles. It is usually known by the appellation of *chemical affinity*, and has hitherto almost exclusively occupied the attention of chemists, on the supposition that it is exclusively the cause of all the compositions and decompositions with which they are conversant; though in fact its influence is neither more extensive nor more important than that of cohesion. Indeed the two powers are so intimately connected, that their actions are very seldom exhibited separately. In treating of heterogeneous affinity, it is necessary to consider, 1. How heterogeneous particles combine; 2. In what proportions they are capable of combining; 3. The force with which they combine; and, 4. What takes place when a variety of heterogeneous particles are made to act upon each other at the same time. These topics will form the subject of the four following Sections.

SECT. I.

OF COMBINATION.

1. WHETHER there exists a reciprocal affinity between every species of the particles of bodies, is a point which cannot easily be determined, though it is certainly very probable that there does. But as the particles of bodies are usually found cohering together in masses, it is evident that no heterogeneous bodies can combine unless their affinity for each other be stronger than the cohesive force which unites the respective particles of each. Now, whenever two bodies constantly refuse to combine, in whatever situation we place them, we say that they have *no* affinity for each other; meaning merely, that their affinity is not so great as to produce combination. Thus we say that there is no affinity between oil and water, because these two liquids refuse to combine together; yet when oil is united with alkali, and in the state of soap, it dissolves in water; a proof that there does exist an affinity between water and oil, tho' not strong enough to produce combination. We say also, that there is no affinity between azot and lime, because azotic gas cannot be combined with that earth: yet nitric acid dissolves lime readily; which shews us that the refusal of lime and azotic gas to combine is not the consequence of the want of an affinity between these two bodies, but of some other cause.

Bodies to be combined; either insulated

2. We may present a body to another with which it is capable of combining in two different states; either insulated or already combined with some other body. Thus we may present lime to nitric acid, either in the state of pure lime, or combined with carbonic acid, and consequently in the state of a carbonat.

In the first case the affinity is opposed by the cohesion, and combination does not take place unless that force can be overcome. Hence the reason that combination seldom succeeds well, unless some of the bodies to be combined be fluid, or be assisted by heat, which has the property of diminishing the force of cohesion. Indeed there are not wanting numerous instances of solid bodies combining together without the assistance of heat; but they are always bodies which have the property of becoming liquid in the act of combination. Thus common salt and snow, muriat of lime and snow, &c. combine rapidly when mixed, and are converted into liquids.

It is to the force of cohesion that the difficulty of dissolving the diamond, the sapphyr, and many other natural bodies is to be ascribed, though composed of ingredients very readily acted on by solvents when their cohesive force is sufficiently diminished. If pure alumina be formed into a paste, and heated sufficiently, it becomes so hard that no acid can act upon it; yet its nature is not in the least changed: by proper trituration it may be again rendered soluble; and when precipitated from this new solution it has recovered all its original properties. The effect of the fire, then, was merely to increase the cohesion, by separating all the water, and allowing the particles to approach nearer each other.

3. Even when the cohesive force of the particles to

be combined is not very great, it may be still sufficient to prevent combination from taking place, provided the other body can only approach it in a very small mass. Hence the reason that carbonic acid gas, and other elastic fluids, have scarcely any action on the greater number of bodies, though they combine with them readily when the force of cohesion presents no opposition. Thus the oxygen of the atmosphere does not combine with sulphur in its natural state, though it unites with it readily when the sulphur is combined with hydrogen and potass, bodies which diminish its cohesion very considerably, or when it is converted into its integrant particles by the action of heat.

Or previously combined;

4. In the second case, or when the body presented to be combined with another is already in combination with some other body, it does not altogether leave the old body and combine with the new, but it is divided between them in proportion to the mass and the affinity of these bodies. Thus when lime, already in combination with phosphoric acid, is presented to sulphuric acid, it does not altogether leave the phosphoric to combine with the sulphuric acid, but it divides itself between these two acids, part combining with the one and part with the other, according to the respective quantities of each of these acids, and the strength of their affinity for the lime. This important point has been lately put in a very clear light by Mr Berthollet. Chemists had formerly in a great measure overlooked the modification produced on the action of heterogeneous bodies on each other by the different proportions of each; supposing that in all cases a substance A, which has a stronger affinity for C than B has, is capable of taking C altogether from B, provided it be added in

And then they are parted between the two acting bodies.

Book III.

sufficient quantity, how great soever the proportion of B exceeds that of A. Several exceptions, indeed, had been pointed out to this general law. Thus Cavendish ascertained, that lime-water is incapable of depriving air completely of carbonic acid. But Berthollet has demonstrated, that this pretended law never holds; that no substance whatever is capable of depriving another of the whole of a third, with which it is combined, except in particular circumstances, however strong its affinity for that third may be, and in how great a proportion soever it be added. Thus no proportion of lime whatever is capable of depriving the carbonat of potass of the whole of its acid. Neither does sulphuric acid decompose phosphat of lime completely, nor ammonia sulphat of alumina, nor potass sulphat of magnesia.

In short, it may be considered as a general law in chemistry, that the smaller the proportion of a body in combination with a given quantity of another body is, with the greater energy is it retained; so that at last the force of its affinity becomes stronger than any direct force that can be applied to separate it. Hence the impossibility of depriving sulphuric acid and several other bodies completely of water

Bodies act in proportion to their mass.

Berthollet has shown also, that every body, how weak soever its affinity for another may be, is capable of abstracting part of that other from a third, how strong soever the affinity of that third is, provided it be applied in sufficient quantity. Thus potass is capable of abstracting part of the acid from sulphat of barytes, from oxalat of lime, phosphat of lime, and carbonat of lime: soda and lime abstract part of the acid from sulphat of potass, and nitric acid abstracts part of the base from oxalat of lime. Hence it follows that substances are capable of decomposing each other reciprocally, provided they be added respectively in the proper quantity. Indeed this was known formerly to be the case, though it had not been considered as a general law till Berthollet drew the attention of chemists to it. Sulphuric acid decomposes nitrat of potass altogether by the assistance of heat. The nitric acid is driven off, and there remains behind sulphat of potass with an excess of acid. On the other hand, if nitric acid be poured into sulphat of potass in sufficient quantity, it takes a part of the base from the sulphuric acid. In the same manner phosphoric acid decomposes muriat of lead, and muriatic acid on the other hand decomposes phosphat of lead.

This reciprocal decomposition follows as a consequence from the nature of affinity. For if the affinity of one particle for another be an absolute force (supposing the distance, figure, and density constant), it certainly ought to follow that this force must be increased by the number of the attracting particles. If a particle A attract a particle B with a force $= x$, two particles A concurring together ought certainly to attract with a force $= 2x$, or at least with a force $= y > x$. Hence we see that the aggregate force of attraction ought to increase with the aggregate number of particles.

Decomposition explained.

But this increase is not sufficient to explain the cause of decomposition. For undoubtedly, how much soever we suppose the attraction of a body A for another body C, to exceed the attraction of B already in combination with C, the addition of A, in how large a quantity soever, cannot be conceived to destroy the combination of B with C, unless some other cause intervene. The attraction between B and C cannot be annihilated, though it may be considerably diminished; it must

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therefore be sufficient to keep the two bodies still united, notwithstanding the presence of A. A, no doubt, will also combine with C; the consequence of which would be a new compound, into which all the three bodies equally enter. This, indeed, must always happen when different bodies are mixed together, whatever their affinities for each other may be, unless some force or other intervene to determine the exclusion of some particular bodies. Thus, if the particles A and C, (supposing them numerous) have not only a strong affinity for each other, but also a strong force of cohesion, which leads the combined particles A + C to unite together and to form masses of sensible magnitude, the particles B may be excluded from these masses either totally or partially, according to their nature, while the masses themselves, becoming too heavy to remain suspended in a fluid, precipitate to the bottom. Hence the reason that barytes precipitates sulphuric acid completely from most of its combinations, and that muriatic acid has the same effect upon silver. Again, if the particles B are elastic, the addition of A, by weakening the force by which they are retained, conspires with this elasticity; the consequence of which may be, that B may fly off altogether, and leave A and C in combination. Hence the reason that sulphuric acid separates carbonic acid from all its combinations.

The presence of an elastic body, like carbonic acid, constitutes an exception to the general rule, that, other things being equal, the affinities of bodies are as their masses: for the elastic body making its escape constantly as it is disengaged, cannot possibly act by its mass

The presence of an absolutely insoluble body, if

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here be any such, must constitute an exception to both he general rules of Berthollet: For the addition of a ody A, which forms an insoluble compound with C, nay decompose completely the compound B + C. A nd B combining, and forming an insoluble aggregate, nust precipitate completely to the bottom. Hence barytes leaves no sensible quantity of sulphuric acid when ropt into a solution containing that acid; and muriatic cid in the same circumstances leaves no sensible quanity of silver. In this case, too, the body A must act ndependently of its mass; because separating almost instantaneously from the solution, the mass of B, however great, cannot oppose its action.

These remarks are sufficient to give us some notion of the manner in which bodies combine together. Let us now consider the *proportions* in which they are capable of combining.

SECT. II.

OF SATURATION.

THE word SATURATION, like most other technical terms introduced into chemistry before the science had acquired much precision, has been used with a great deal of latitude, being sometimes taken in one sense and sometimes in another. But in order to be understood, it is necessary to use the word with some degree of precision: for that reason I shall, in this Section, confine it to that particular sense which seems best adapted to it.

Saturation explained.

1. If we make the attempt, we shall find that water will not dissolve any quantity of salt that we please. At the temperature of 60°, it dissolves only 0.354 parts of its weight of salt; and if more salt than this be added, it remains in the water undissolved. When water has dissolved as much salt as possible, it is said to be *saturated* with salt. This sense is at least analogous to the original meaning of the word, and is that to which I mean to restrict it in this Section. Whenever, then, a substance A refuses to combine with an additional quantity of another body B, we may say that it is saturated with B. The cause of this refusal of the water to dissolve any more salt has been indicated in the preceding Chapter. It takes place whenever the affinity of the water and salt is balanced by the cohesion of the particles of the salt, and therefore indicates that these two forces are equal.

In the same manner water, after having absorbed a certain quantity of carbonic acid gas, refuses to absorb any more. We may indeed pass carbonic acid gas thro' water in this state, but it makes its escape unaltered. Water which refuses to absorb carbonic acid gas is *saturated* with that acid. This saturation takes place when the affinity between the gas and the water is balanced by the elasticity of the gas, and indicates of course that these two forces are equal.

Consists in the balancing of two forces.

In these two instances the saturation is occasioned by opposite causes. The salt refuses to dissolve in the water when the *cohesion* of its particles equals its affinity for the water; the carbonic acid gas, when the *repulsion* of its particles equals its affinity for water. In the first case, it is the attractive force of cohesion which opposes farther solution; in the second case, it is the epulsive force of elasticity. Hence the different mehods which must be followed to diminish these forces, nd enable the water to dissolve a greater proportion of hese respective bodies. Heat, by diminishing the force f cohesion, enables water to dissolve a greater proporion of saline bodies. Accordingly we find that in most ases hot water dissolves more salt than cold water. Common salt is almost the only exception to this geneal law. On the other hand, cold, by diminishing the elasticity, or at least the expansibility of gaseous bodies, nables water to dissolve a greater proportion of them. Thus the colder the water is, the greater a proportion f carbonic acid is it capable of dissolving. The freeing point of water limits this increase of solubility, ecause at that point the cohesive force of the particles of water becomes so great as to cause them to cohere, to the exclusion of those bodies with which they were formerly combined. Hence the reason that most odies separate from water when it freezes. But they enerally retard the freezing considerably, by opposing with all the strength of their affinity the cohesion of he water. The consequence is, that the freezing point f water, when it holds bodies in solution, is lower than he freezing point of pure water. A table of the freezing oints of different saline solutions would be a pretty ccurate indication of the affinity of the different salts or water: for the affinity of each salt is of course proortional to the degree of cold at which it separates rom the water, that is, to the freezing point of the soution.

In this sense of the word *saturation*, which is certainy the only one that it ought to bear, it may be said with propriety that there are certain bodies which cannot be saturated by others. Thus water is capable of combining with any quantity whatever of sulphuric acid, nitric acid, and alcohol; and all bodies seem capable of combining with almost any quantity whatever of caloric. Several of the metals, too, are capable of combining with any quantity whatever of some other metals. In general, it may be said that those bodies called *solvents* are capable of combining in any quantity with the substances which they hold in solution. Thus water may be added in any quantity, however great, to the acids, and to the greater number of salts.

Neutralization

2. If we take a given quantity of sulphuric acid diluted with water, and add to it slowly the solution of soda by little at a time, and examine the mixture after every addition, we shall find that for a considerable time it will exhibit the properties of an acid, reddening vegetable blues, and having a taste perceptibly sour: but these acid properties gradually diminish after every addition of the alkaline solution, and at last disappear altogether. If we still continue to add the soda, the mixture gradually acquires alkaline properties, converting vegetable blues to green, and manifesting an urinous taste. These properties become stronger and stronger the greater the quantity of the soda is which is added. Thus it appears that when sulphuric acid and soda are mixed together, the properties either of the one or the other preponderate according to the proportions of each; but that there are certain proportions, according to which, when they are combined, they mutually destroy or disguise the properties of each other, so that neither predominates, or rather so that both disappear.

When substances thus mutually disguise each others properties, they are said to *neutralize* one another.

This property is common to a great number of bodies; but it manifests itself most strongly, and was first observed, in the acids, alkalies, and earths. Hence the salts which are combinations of these different bodies received long ago the name of *neutral salts*. When bodies are combined in the proportion which produces neutralization, they are often said to be *saturated;* but in this case the term is used improperly. It would be much better to confine the word *saturation* to the meaning assigned to it in the beginning of this Section, and to employ the term *neutralization* to denote the state in which the peculiar properties of the component parts mutually disappear; for very frequently neutralization and saturation by no means coincide. Thus in *tartrite of potass* the acid and alkali neutralize each other; yet it cannot be said that the potass is saturated; for it is still capable of combining with more tartarous acid, and of forming super-tartrite of potass, a compound in which the ingredients do not neutralize each other; for the salt has manifestly a preponderance of the properties of the acid.

Owing to an equality of affinity.

When two substances neutralize each other, it is not easy to avoid supposing that they are either combined particle to particle, or nearly so. They must at least be combined in such a manner, that the particles of each are distributed everywhere in such equal proportions, that an equal number of both is applied to all bodies in which the compound acts; or rather such a number of each, that its action upon all bodies is exactly equal to the effect of the other. The consequence of this must be, that both of them will act at the same time with equal energy upon every body which is exposed to their action. Hence, as far as their actions are opposite, they will mutually destroy each other; and, as far as they are not exactly opposite, they will produce a compound effect different from what would be produced by either singly; just as the mixture of two rays of light produces a colour different from the colour produced by each separately.

When bodies neutralize each other, they must be considered as in the most perfect state of combination possible, as they exactly balance each other. Consequently if a body A neutralizes a body B, the two are united in such proportions that the absolute force of the affinity of A for B is equal to that of B for A.

3. A question still remains to be resolved concerning the proportion in which bodies combine, which is attended with very considerable difficulty: Are bodies capable of combining with each other indefinitely, or do they only combine with each other in certain determinate proportions? The observations already made may seem to decide in favour of the first of these suppositions; but let us consider the subject a little more precisely.

Bodies only unite in certain proportions.

Let us suppose two bodies, *a* and *b*, to have an affinity for each other. Let us take one particle of *a* and combine it with as many particles of *b* as can approach within *a*'s sphere of affinity. It is clear that in this case *a* is absolutely saturated with *b*, and cannot possibly combine with any more particles of that body. Let us call the new compound $a + x b$. If the particles of *b* have a cohesive force, it is very possible that they may combine indefinitely with the compound $a + x b$; but this combination cannot with propriety be considered as the union of more particles of *b* with *a*; it would have taken place if *a* had not been present at all, and must be ascribed entirely to the cohesion of the particles of *b*. Now if, instead of one particle of *a*, we suppose two or a thousand, the case will remain the same. Each particle may combine with as many particles of *b* as can come within the sphere of its attraction; but all additions of *b* beyond that must be ascribed entirely to the cohesion of the particles of *b*. Thus if *a* remains constant, we see that it can only combine with a finite portion of *b*; consequently in those cases where saturation is impossible, the new doses of the solvent must be considered as combining merely with the solvent, and not with the body held in solution.

There is a maximum and minimum beyond which they cannot pass,

The same observation holds, if we suppose *b* constant and *a* variable. Indeed if we were to consider the reciprocal attractions of the particles of both bodies, and the spheres of attraction which surround every particle, it would be an extremely difficult matter to form any adequate notion of the manner in which they combine and act upon each other. But it is easy to see in general, that if the particles of a body *a* remain constant, they can only combine with a limited number of particles of another body *b*, because only a limited number can come within the spheres of their attraction.

Thus we see, that, strictly speaking, a given body *a* cannot combine with a body *b* beyond a certain proportion. But is there a limit on the other side? Can *a* combine with any quantity of *b*, however small, provided it be within the maximum? or is it necessary that, before any combination can take place, a certain definite proportion of *b* must be present? What is the minimum of *b* that can combine with a given portion of *a*?

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It is evident that if a has an affinity for b, one particle of each must be capable of combining together; at least nothing can be conceived to hinder them. But this does not answer the question; for we must suppose a considerable number of particles of a present. Let us then make $x\,a =$ number of particles of a, which can approach within the sphere of attraction of a particle of b, and $y\,x\,a =$ quantity of a present; it is evident from what has been said before, that $y\,b$ is the minimum which is capable of combining with $y\,x\,a$. If less be added, part of a will remain combined only by cohesion. If this cohesion does not exist, then it is impossible that a and b can remain in combination in any proportion less than $y\,x\,a$ and $y\,b$. Accordingly in water, where the component parts are elastic fluids, we find them always united in one determinate proportion. In this compound the maximum and minimum coincide apparently: We are not yet far enough advanced in our notions of affinity to say why. And in the metallic oxides, where one of the component parts is an elastic fluid, the minimum as well as the maximum consists of a precise proportion of oxygen.

Thus it appears, that in all combinations there are two precise limits, a minimum and a maximum, beyond which the component parts can never pass. It remains still for us to consider whether they can combine in any proportion within these limits. For instance, if the minimum of oxygen capable of combining with iron be 0.25, and the maximum 0.48, the question to be decided is, Can iron combine with any proportion whatever of oxygen between 0.25 and 0.48? or can it only combine with certain determinate proportions, such as 0.30 or 0.40?

Whether they combine indefinitely within these limits.

When we consider the matter abstractedly, we can perceive nothing to prevent this combination of bodies in any proportion whatever within the limits of their maxima and minima; though it must be acknowledged that it would be exceedingly difficult to form any adequate notion of the manner in which they are combined in these circumstances. This indefinite combination seems formerly to have been considered as an axiom by chemists. It was abandoned, perhaps with too much facility, in consequence, chiefly, of the experiments of Lavoisier; but the opinion has lately been revived again, and supported with much ingenuity by Berthollet. Let us consult experience, which is alone capable of deciding the point: for our notions of affinity are still too imperfect and confused to warrant any deductions from abstract reasoning.

Now, as far as experience has gone, substances, if we attend only to the proportions in which they combine with each other, may be arranged under four classes.

1. Some seem to combine in any proportion whatever between the maxima and minima.

2. Some combine only in certain determinate proportions between the maxima and minima.

3. Some combine only in the proportions which constitute the maxima and minima.

4. In some the maximum and minimum coincide, so that they are capable of combining only in one determinate proportion. Let us consider each of these classes a little.

The *first* class, strictly speaking, scarcely includes any bodies except those which are incapable of saturation, and which therefore have a minimum but no visible maximum. Thus water is capable of combining with common salt in any proportion whatever beyond the minimum capable of holding the salt in solution. It holds also with all substances which are in solution, and which remain in solution, both at the maximum and minimum of combination. Thus the acids are capable of combining with alkalies, and with those earths which form soluble salts in any proportion below saturation.

To the *second* class belong almost all combinations of oxygen with other bodies. Thus all the simple combustibles except hydrogen are always found combined with oxygen in certain determinate proportions, and can only be combined artificially in these proportions. Thus we have

1. Sulphur	Oxide of sulphur, Sulphurous acid, Sulphuric acid.
2. Phosphorus	Oxide of phosphorus, Phosphorous acid, Phosphoric acid.
3. Carbon	Charcoal, Oxide of carbon, Carbonic acid.
4. Azot	Air, Oxide of azot, Nitrous gas, Nitric acid.

With respect to the metallic oxides, our knowledge is not sufficiently precise to be able to decide with confidence. Several of them, as those of lead, seem to belong to the first class; but others, as those of mercury, belong pretty evidently to the second

To the *third* class belong several of the metallic xides, which have been examined with the greatest preision, as those of iron, tin, copper, arsenic. In some of em, the capacity of only combining in the maximum nd minimum proportion is exceedingly well marked. hus the red oxide of iron is converted by heat and by ulphurated hydrogen gas to the black oxide: if the lack oxide of copper and metallic copper be mixed toether in equal quantities in muriatic acid, the oxygen oes not divide itself among the whole of the copper; uch a portion of the metal only is oxidated as with the xygen is capable of forming orange oxide, and the rest f the copper remains unaltered. If copper-filings be onfined with muriatic acid in a phial half full and close orked, the acid at first acquires a deep green colour, nd of course has combined with a portion of the copper, hich must previously have been converted into black xide; but in a few days it becomes quite colourless. he black oxide is gradually decomposed, more copper is issolved, and acid is found combined, not with the black ut with the orange oxide. Here the process stops, uness we uncork the phial for a few minutes. If that be one, the solution becomes again green, and gradually oses its colour as before. If the phial be opened under ater, a quantity of that liquid rushes in; a plain proof hat part of the air of the phial has disappeared: and if e examine that air, we find it deprived altogether of ts oxygen. The nature of the process then is evident: he copper is supplied with oxygen from the air in the essel. It at first combines with it in that proportion nly which constitutes black oxide; afterwards this black xide, or rather oxy-muriat, combines with the precise ortion of copper necessary to convert it to orange xide or muriat. If air be again presented, the muriat combines with the precise proportion of oxygen which is necessary to convert it into muriat, and so on.

To the *fourth* class belongs *water*, which cannot by any method known be combined in any other proportion than 0.85 oxygen and 0.15 hydrogen. *Ammonia* also belongs to the same class, for it is equally constant in its proportions. It is remarkable that both the component parts of these two bodies are elastic fluids. This elasticity is doubtless the cause of the constancy of the proportions; for it is obvious that there can be only one proportion capable of holding the elasticity of the two component parts in due balance; and if the elasticity of either prevail, the combination cannot take place at all. Substances which are absolutely insoluble, or nearly so, when combined in certain proportions, may also be considered as belonging to the same class, unless the addition of either of the ingredients renders them soluble. Hence the reason of the constancy of the proportions of sulphat of barytes, oxalat of lime, phosphat of lime, fluat of lime, &c.

All compounds belonging to the second and third class have an elastic fluid for one of their ingredients, and those of the third class only manifest their peculiar constitution when they are in combination with some other substance. These observations are sufficient to show that the refusal of bodies to combine, except in their maximum or minimum proportion, or in certain determinate proportions between these two, is owing always, not to the nature of affinity, but to certain peculiarities in their constitution; and that when these peculiarities are not present, these determinate proportions are not observed. But this peculiarity of constitution deserves the highest attention, as we are indebtto it for that constancy which we find in almost all mbinations, and for the permanency of natural bo-es in the state in which they have originally combi-d.

Having thus examined the proportions in which bo-es are capable of combining, let us now consider the rieties in the *force* with which they combine, and the tempts which have been made to measure these va-ties.

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OF THE STRENGTH OF AFFINITY.

Importance of the subject.

INCE the affinity of almost every two bodies for each her differs *in strength* from that between every other o, it becomes an important problem *to determine the rength of every affinity in numbers*. The solution of is problem would give a clearness and precision to emistry equal to that of any other branch of natural hilosophy whatever, and enable it to advance with a egree of rapidity hitherto thought unattainable. No onder, then, that this problem has occupied the at-ention of some of the most eminent philosophers who ave dedicated their time to chemistry. Let us consi-er the different attempts which have been made to re-olve it, that we may see whether any of them will an-wer the end proposed.

Solution proposed by Wenzel,

Wenzel supposed that the time taken by one body o dissolve another is a measure of the affinity which subsists between them. But the hypothesis of that ingenious philosopher will not bear the test of examination; for the *time* of solution evidently depends upon circumstances unconnected with affinity. The cohesion of the body to be dissolved, and the nature of the compound formed, must occasion very great differences in the time of solution of different bodies, even on the supposition that their affinities were all the same.

By Fourcroy,

Fourcroy proposed to measure the affinity of bodies by the difficulty of separating them after they are combined: but we have no method of measuring this difficulty. Lavoisier and De la Place, indeed, proposed *caloric* for this purpose; but there are many compounds which caloric cannot separate, and it never produces a separation except by means of its affinity for one or other of the ingredients of the compound. Before caloric, therefore, could be employed as a measure, it would be necessary to know exactly the strength of its own affinity for every other substance; which is just a case of the problem to be resolved.

By Macquer,

Macquer supposed that the affinity of bodies for one another was in the compound ratio of the facility of their union, and the difficulty of their separation. But as we are in possession of no method of ascertaining either of these, it is evident that this theory, even allowing it to be just (which it certainly is not), could be of no use for assisting us to calculate the force of affinities.

By Morveau.

Another method has been proposed by the distinguished philosophical chemist Mr de Morveau *.

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* Now Mr Guyton. We have used the old name all along in the text to avoid ambiguity.

In 1713, Dr Brook Taylor made some experiments the adhesion of surfaces; and concluded from them, at the force of adhesion might be determined by the eight necessary to produce a separation. But in 1772, essrs La Grange and Cigna, observing that the surces of water and oil adhere together, and taking it r granted that these two liquids *repel* each other, ncluded, in consequence, that their adhesion was not ving to *atraction*; and hence inferred, that *adhesion*, general, is always owing to the pressure of the atosphere. This conclusion induced Morveau to exaine the subject: he found, that adhesion was *not afcted* by the pressure of the atmosphere; for it requid the same weight to separate a disk of glass (30 lines diameter) from the surface of mercury in the open r, and under an exhausted receiver. He observed at the same disk adhered to water with a force of 258 ains, and to the solution of potass, though denser, ly with a force of 210. This result not only proved at adhesion was owing to attraction, but made him nceive the possibility of applying this method to the lculation of affinities: For the force of adhesion beg necessarily proportional to the points of contact, d this being the case also with affinity, it is evident, at the adhesion and the affinity between the same subances are proportional, and that therefore the knowdge of the one would furnish us with the ratio of the her.

Struck with this idea, he constructed cylinders of fferent metals, perfectly round, an inch in diameter d the same in thickness, and having a small ring in eir upper surface, by which they might be hung exctly in equilibrium. He suspended these cylinders, one after another, to the beam of a balance; and after counterpoising them exactly, applied them to a quantity of mercury placed about two lines below them, making them slide along its surface, to prevent any air from lodging between them and the mercury. He then marked exactly the weight necessary to overcome their adhesion, taking care to change the mercury after every experiment. The Table of the results is as follows:

Gold adheres to mercury with a force of	446 gr.
Silver	429
Tin	418
Lead	397
Bismuth	372
Platinum	282*
Zinc	204
Copper	142
Antimony	126
Iron	115
Cobalt	8

The differences of these results cannot be owing to the pressure of the air, which was the same in all; nor do they correspond to the densities of the metals; nor can they be owing to accidental differences in the polish of the cylinders, for a plate of rough iron adheres more strongly to mercury than one of the same diameter exquisitely polished; but they follow precisely the order of affinity, and therefore may be considered as the measure of the strength of the affinity between these different metals and mercury. They furnish us also with a convincing proof that *affinity* is *attraction*, and

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* Morveau, *Ann. de Chim.* xxv. 10.

e same species of attraction with *adhesion* ; and that
erefore, if the one be reducible to *gravitation*, so must
e other.

Mr Achard, convinced of the importance of Mr Mor-
au's observations, made a great many experiments on
lhesion, and published the result of them in 1780. He
oved that the force of adhesion is not affected by
terations in the height of the barometer, but that its
rce becomes weaker as the heat of the fluid increased[*];
id that the temperature remaining the same, the force
adhesion increases in the same ratio with the surfa-
s of the adhering bodies. He made about 600 expe-
ments on the adhesion of different solids and fluids;
roved that the force of adhesion did not depend on the
nsities of the adhering bodies, nor on the different co-
sive force of the fluids; and, after a laborious calcu-
tion, concluded, that it depended on the figure of the
articles of the adhering fluid and solid.

This method of measuring the force of affinities seems
be an accurate one, and if it could be applied to eve-
y case of affinity, would, in all probability, enable us
solve the problem which we are now considering:
ut unfortunately its application is very limited, being
onfined to those cases alone in which one of the bodies
an be presented in a fluid and the other in a solid state.
Nor can it be applied indiscriminately to all those cases;
or whenever the cohesion of any liquid is much infe-
ior to the force of its adhesion to any solid, the sepa-
ation takes place in the particles of the liquid itself,
nd consequently we do not obtain the measure of its

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[*] Strictly speaking, this is owing not so much to a decrease of the
orce of adhesion, as that of the cohesion of the fluid itself.

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adhesion to the solid, but of its own cohesion, and that too imperfectly. Thus, for instance, Mr Achard found, that sealing-wax adhered to water with a force of 92 grains, and to alcohol only with a force of $53\frac{1}{4}$ths; yet we know that sealing-wax has a greater affinity for alcohol than for water: because alcohol dissolves it, which water is incapable of doing. The difference in the result in this instance was evidently owing to the smaller cohesion of alcohol. Mr Morveau's method must therefore be confined to those cases in which the cohesion of the liquid is stronger than its adhesion to the solid, which may be known by the surface of the solid not being moistened, and to those in which the cohesion is not much inferior to the adhesion; for then it is evident that the force of cohesion will be increased as the force of adhesion. Let us suppose, for instance, that two solids, A and B, are made to adhere to the surface of a liquid, and that A can only form an adhesion with 50 particles of the liquid, whilst B adheres to 100; it is evident that a much smaller force will destroy the cohesion of the 50 particles to which A adheres with the rest of the liquid, than what will be required to destroy the cohesion of the 100 particles united to B with the same liquid *.

The method of Mr Morveau, then, may be applied with accuracy in both cases; and *when* they occur can only be determined by experiment. It cannot, however, be applied indiscriminately even then; for unless the solid and the fluid be presented in such a state that no gas is extricated when the adhesion takes place, an accurate judgment cannot be formed of the force of ad-

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* Morveau, *Encyc. Method. Chim.* art. *Adhesion.*

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sion. When marble (carbonat of lime), for instance, applied to the surface of sulphuric acid, there is an trication of gas, which very soon destroys the adhe- n, and prevents an accurate result. Were it pos- le to employ quicklime instead of marble, this would prevented ; or if this cannot be accomplished, why ight not lime be employed, united with some acid that ould not assume a gaseous form, and at the same time s a weaker affinity than sulphuric acid for lime? Why ight not the phosphat of lime, for instance, be used, ich may be reduced to a state of hardness sufficiently eat for the purpose? The extrication of gas, during e application of metals to the surfaces of acids, might prevented by oxidating their surfaces. It is true, deed, this could not be done with all the metals, on count of the nature of the oxide, but it might with veral ; copper, for instance, and silver. It cannot be ubted, that by these methods, and other contrivances at might be fallen upon, a sufficient number of results ight be obtained to render this method of the greatest portance. It is rather surprising, therefore, that it s never been prosecuted.

By Kirwan.

Mr Kirwan has proposed another method of solving e problem. While he was engaged in his experiments the strength of acids, he observed that the quantity real acid necessary to saturate a given quantity of ch of the bases was inversely as the affinity between e respective bases and the acid ; and that the quan- ty of each of the bases necessary to saturate a given antity of acid was directly as the affinity between the se and the acid. Thus 100 grains of each of the ids require more alkali for saturation than lime, and more lime than magnesia, as may be seen in the following TABLE:

100 Grains of	Potass.	Soda.	Lime.	Amm.	Mag.	Alu
Sulphuric acid	215	165	110	90	80	75
Nitric acid	215	165	96	87	75	65
Muriatic acid	215	158	89	79	71	55

He concluded, therefore, that the affinity between acids and their bases may be estimated by the quantity of bases necessary for saturation. Thus the affinity between potass and sulphuric acid is 215, and that between nitric acid and lime 96*.

Bergman long ago established as a principle, under the name of a chemical paradox, that *the stronger any salt was, the less of any other it required for saturation*. Thus, according to him,

100 parts of potass require	78.5	Sulphuric acid
	64	Nitric
	51.5	Muriatic
	42	Carbonic
100 parts of soda	177	Sulphuric
	5.5	Nitric
	125	Muriatic
	80	Carbonic

This proposition, which has been admirably illustrated by Morveau †, evidently resolves itself into the two following:

1. A *base* requires *the more* of an acid for saturation *the stronger* its affinity for that acid is.

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* *Phil. Trans.* 1783.

† *Encyc. Method. Chim.* 1.597.

2. An acid requires *the more* of any base for satura- ion *the greater affinity* it has for that base.

This axiom of Bergman coincides exactly with the bservations of Mr Kirwan; but as it is merely empy- ical, and as it is often contradicted by the latest expe- ments on the analysis of salts published by Kirwan, it ill be necessary to suspend our judgment till these nalytical methods are brought to such a degree of per- ection as to decide the point.

By Berthollet.

Berthollet has lately proposed another method of es- imating the strength of affinity, founded on the prin- iples which he himself first developed. This method ives results which deviate if possible still more wide- y from the received order of affinities than the axiom f Bergman and Kirwan; but as he has given sufficient easons to convince us that the received order of affini- es is often erroneous, it will be worth while to take view of his method, in order to discover what new ght it will give us to develope the still unknown ws of the variations of affinity.

As the affinities of bodies vary with their mass, it is bvious that, when we consider the affinities of bodies, e must suppose them always acting in certain deter- inate proportions. Now it has been observed for- erly, that there are certain proportions in which bo- ies neutralize each other; and there is reason to be- eve that in these proportions the affinity exerted by ach of the component parts is precisely of the same orce. Now if we suppose that the affinity of a given ass of a given body is a constant quantity, which is at east highly probable; if we suppose farther, that the ffinity of a body is the sum of the attractions of all its articles, and consequently that when various bodies of different masses exert the same affinity, the absolute affinity of each body is inversely as its mass—we have a method of ascertaining the proportional affinities of various bodies for a body A: for the affinity of each body must be inversely as the mass of each body capable of neutralizing a given quantity of A. Let it be supposed required to find the proportional affinity of the three bodies *b*, *c*, and *d* for A. If to neutralize a given weight of A = 1, there be required of

b a weight = 1
c . . . . . = 2
d . . . . . = 3

Then the affinities of *b*, *c*, and *d* for A are respectively as the inverse of the numbers 1, 2, and 3.

Affinity of *b* = 1 or 6
c = $\frac{1}{2}$ or 3
d = $\frac{1}{3}$ or 2

Such is the method pointed out by Berthollet, or at least the method which follows as a consequence from his observations. Let us compare it with the late experiments of Kirwan, which may be considered as the most accurate determinations of the proportions of acid and alkali which neutralize each other. These TABLES are the following:

They give us the affinities of the different bases for sulphuric, nitric, muriatic, and carbonic acids, in the following order and intensity.

Mr Kirwan's Table *of the Composition of Salts.*

Salts.	Component Parts. Basis.	 Acid.	 Water.	State.
Carbonat of potass	41.	43.	16.	Crystallized.
Pearl ash	60.	30.	6.	Dry.
Carbonat of soda	21.58	14.42	64.	Fully crystallized.
ditto	59.86	40.05		Desiccated.
barytes	78.	22.		Natural or ignited.
strontian	69.5	30.		Natural or ignited.
lime	55.	45.		Natural if pure, or artificial ignited.
magnesia	25.	50.	25.	Crystallized.
common do.	45.	34.	21.	Dried at 80°.
Sulphat of potass	54.8	45.2		Dry.
soda	18.48	23.52	58.	Fully crystallized.
ditto	44.	56.		Desiccated at 700°.
ammonia	14.24	54.66	31.1	
barytes	66.66	33.33		Natural and pure, artificial ignited.
strontian	58.	42.		Natural and pure, artificial ignited.
lime	32.	46.	22.	Dried at 66°.
ditto	35.23	50.39	14.38	Dried at 170°.
ditto	38.81	55.84	5.35	Ignited.
ditto	41.	59.		Incandescent.
magnesia	17.	29.35	53.65	Fully crystallized.
ditto	36.68	63.32		Desiccated.
Alum	12. ignited	17.66	51. of crystal. + 19.24 in the earth	Crystallized.
Ditto	63.75	36.25		Desiccated at 700°.

TABLE *of the Composition of Salts, continued.*

Salts.	Component Parts.			State.
	Basis.	Acid.	Water.	
Nitrat of potass	51.8	44.	4.2 of Composition	Dried at 70°.
soda	40.58	53.21	6.21 of Composition	Dried at 400°.
ditto	42.34	57.55		Ignited.
ammonia	23.	57.	20.	
barytes	57.	32.	11.	Crystallized.
strontian	36.21	31.07	32.72	Crystallized.
lime	32.	57.44	10.56	Well dried, that is, in Air.
magnesia	22.	46.	22.	Crystallized
Muriat of potass	64.	36.		Dried at 80°.
soda	53.	47. aqueous, 38.88 real		Dried at 80°.
ammonia				Crystallized.
ditto	25.	42.75	32.25	Sublimed.
barytes	64.	20.	16.	Crystallized.
ditto	76.2	23.8		Desiccated.
strontian	40.	18.	42.	Crystallized.
ditto	69.	31.		Desiccated.
lime	50.	42.	8.	Red hot.
magnesia	31.07	34.59	34.34	Sensibly dry.

Tables of real affinities.

I. SULPHURIC ACID.

	Intensity.
Ammonia	383
Magnesia	171
Lime	143
Soda	127
Potass	82
Strontian	72
Barytes	50

II. NITRIC ACID.

	Intensity.
Ammonia	245
Magnesia	209
Lime	179
Soda	136
Potass	85
Strontian	85
Barytes	56

III. MURIATIC ACID.

	Intensity.
Ammonia	171
Magnesia	111
Lime	84
Soda	73
Potass	56
Strontian	46
Barytes	31

IV. CARBONIC ACID.

	Intensity.
Ammonia	
Magnesia	200
Lime	81
Soda	66
Potass	105
Strontian	43
Barytes	28

The order and intensity of these four acids for the same bases may be seen from the following TABLE :

Acids.	Potass.	Soda.	Amm.	Baryt.	Stront.	Lime.	Magn.
Muriatic	177	136	58	314	216	118	80
Sulphuric	121	78	26	200	131	69	57
Nitric	117	73	40	178	116	50	47
Carbonic	95	149		35	231	122	50

In these Tables we see that the affinities follow the same order, except in the case of carbonic acid, from the nature of which it is not so easy to determine in what proportion it combines with the various bases as it is to determine the same thing with regard to the other acids.

In the first set of tables, we see that the bases follow precisely the inverse order of what is commonly supposed to be their affinities, and which have been given from Bergman in the preceding part of this Work. Ammonia has the strongest affinity for the acids, and barytes the weakest. This is contrary to the order in which these substances decompose, or rather precipitate each other. Consequently if it be the real order of the affinities of the bases for the acids, decomposition must be determined by something else than the force of affinity.

Why the order of affinity and of decomposition may be different.

If we consider the matter with attention, it will not be difficult to see the reason why the order of affinity and of decomposition is different: Ammonia is an elastic fluid, of course it makes its escape as soon as it is disengaged; and its elasticity conspires to render its disengagement more easy. Hence any substance, how weak soever its affinity is, may be capable of disengaging it from its combination, provided it be added in sufficient quantity and the decomposition be assisted by heat. The disengagement of ammonia then by the other bases is no sufficient proof that its affinity is inferior to them.

Magnesia forms with sulphuric acid a very soluble compound; hence the reason that sulphuric acid is separated from it by barytes, strontian, lime, and potass. These bodies form salts scarcely soluble, and therefore the attraction of cohesion enables them to abstract the acid, notwithstanding the inferiority of their affinity. Magnesia, too, has a strong tendency to cohere together in visible masses. This cohesive tendency is sufficient to enable soda to displace it from sulphuric acid.

This tendency to cohesion may be the reason why me is precipitated from its solution in acids in several stances by potass and soda The superiority of potass ver soda has been determined merely on account of e greater insolubility of most of the salts of potass. he same thing has occasioned the supposed superiority f barytes over strontian.

But it would be tedious to examine all the different lts particularly. The causes of their decomposition, even n the supposition that their real affinities are as in the ove Tables, will easily suggest themselves, at least fter the perusal of the next Section.

With respect to the affinity of the acids for the re- ective bases, they follow the order which has long een recognized in the metallic salts; muriatic acid rst, then the sulphuric, and the nitric in the third lace. The carbonic acid ought not to be taken into nsideration, because the composition of the salts, into hich it enters, must still be considered as very imper- ctly determined. The reason why muriatic acid has en supposed to have a weaker affinity for the alkalies nd earths than sulphuric acid is, that its salts are much ore soluble than those into which sulphuric acid en- rs.

Upon the whole, then, we may consider it as exceed- gly probable that the real order of affinities does not eviate far from that given in the above Tables. The ethod pointed out by Berthollet, for determining the rength of affinities, therefore, will probably lead to nsequences of the greatest importance. It will oblige hemists to attend more closely to the reciprocal ac- on of bodies on each other, and the result must be e discovery of several general laws, which will greatly facilitate the acquisition and the advancement of th science. Even already some of these have been lai open by Berthollet, as we shall see in the next Section.

SECT. IV.

OF COMPOUND AFFINITY.

ALTHOUGH every chemical combination is produce by the same general law, yet as their phenomena var somewhat according to circumstances, affinities have for the sake of greater perspicuity, been divided int classes. These classes may be reduced to two, namely *simple* affinity and *compound* affinity.

Simple affinity.

The *first class* comprehends all those cases in whic only *two bodies combine* together; as, for instance, sulphuric acid and potass, oxygen and carbon. The affinities which belong to this class are known by the nam of *simple* or *single affinities*. Although one of the substances to be combined happens to be already unite with another body, the combination is still reckoned case of single affinity. Thus suppose the sulphuric aci previously combined with magnesia, and forming wit it the salt called *sulphat of magnesia*, as soon as potas is presented, the acid leaves the earth (which is precipitated) and unites with the alkali. Even when thre bodies combine, it often happens that the union is produced merely by single affinity. Thus, when some potass is dropped into tartarous acid, part of the acid unite with the alkali, and forms tartrite of potass; after thi

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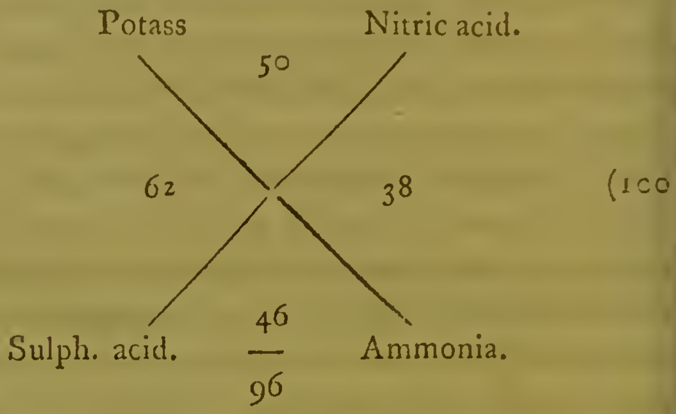
he remainder of the acid combines with the tartrite ust formed, and composes a new salt known by the ame of *super-tartrite of potass*, or *tartar*. This is vidently nothing else than two instances of simple affi-ity immediately following each other.

Compound affinity.

When more than three bodies are mixed, decomposi-ions and new combinations often take place, which vould not have been produced had the bodies been pre-ented in a separate state. If, for instance, into a solu-ion of sulphat of ammonia there be poured nitric cid, no decomposition is produced, because the sul-huric acid has a stronger affinity for ammonia than itric acid has. But if nitrat of potass be poured in, ve obtain by evaporation two new bodies, *sulphat of otass* and *nitrat of ammonia*. Such cases of decompo-ition form the *second class of affinities*. They were alled by Bergman cases of *double elective attraction*; name which is exceedingly proper when there are only our bodies concerned. But as there are often more han four, it is necessary, as Mr Morveau has observed, to employ some more comprehensive term. The phrase *compound affinity* may be employed with propriety, comprehending under the term all cases where more than three bodies are present, and produce combinations which would not have been formed without their united action. In these cases the affinity of all the va-rious bodies for each other acts, and the resulting combination has been supposed to be produced by the action of those affinities which are strongest.

The manner in which these combinations and decompositions take place, was thus explained by Dr Black. Let the affinity between potass and sulphuric acid be = 62; that between nitric acid and ammonia = 38;

that between the same acid and potass = 50; and that between the sulphuric acid and ammonia = 46. Now, let us suppose that all these forces are placed so as to draw the ends of two cylinders crossing one another, and fixed in the middle in this manner,



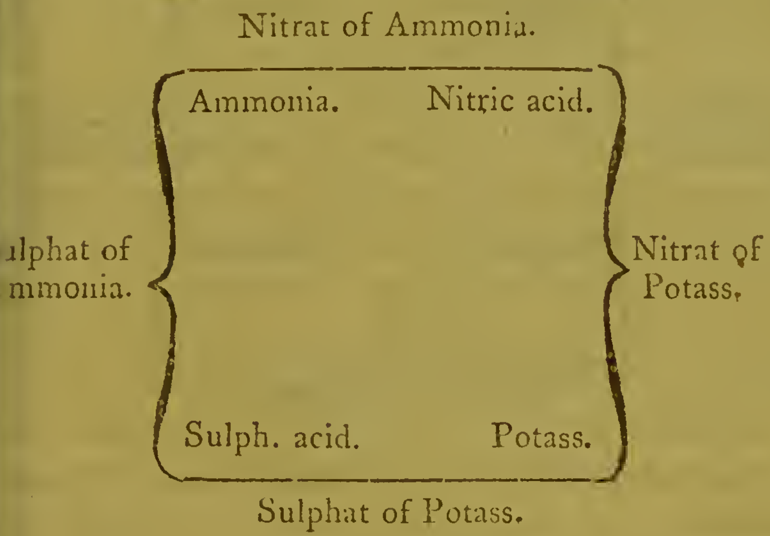
It is evident, that as 62 and 38 = 100 are greater than 50 + 46 = 96, they would overcome the other forces and shut the cylinders. Just so the affinity between ammonia and nitric acid, together with that between sulphuric acid and potass, overcomes the affinity between ammonia and sulphuric acid, and that between nitric acid and potass, and produces new combinations.

It has been supposed that in all cases of compound affinity, there are two kinds of affinities to be considered; 1*st*, Those affinities which tend to preserve the old compound, these Mr Kirwan has called *quiescent* affinities; and those which tend to destroy them, which he has called *divellent* affinities.

Thus, in the instance above given, the affinity between ammonia and sulphuric acid, and that between nitric acid and potass, are quiescent affinities, which endeavour to preserve the old compound; and if they are strongest, it is evident that no new compound can

ke place. On the contrary, the affinity between potass
ıd sulphuric acid, and that between nitric acid and
nmonia are divellent affinities; and as they are in this
se strongest, they actually destroy the former combi-
tions and form new ones.

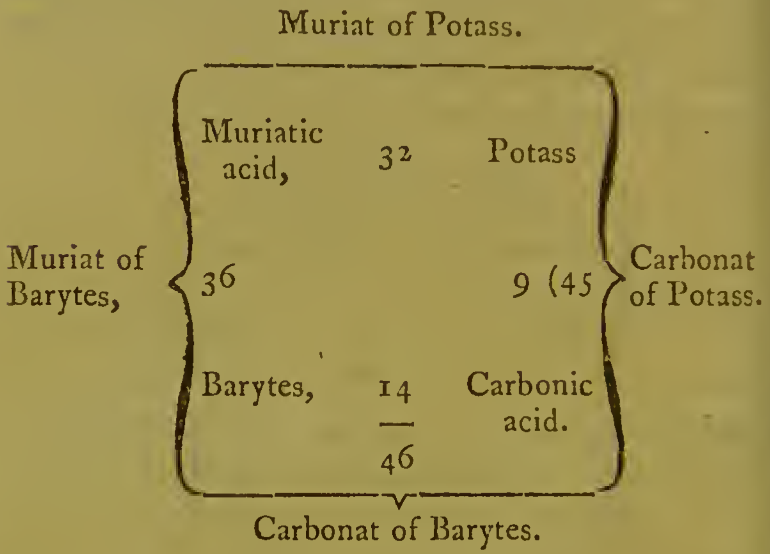
Bergman, who published a great many cases of com-
und affinities, employed to explain them a method
mewhat different from this. He would have repre-
nted the above case in the following manner:



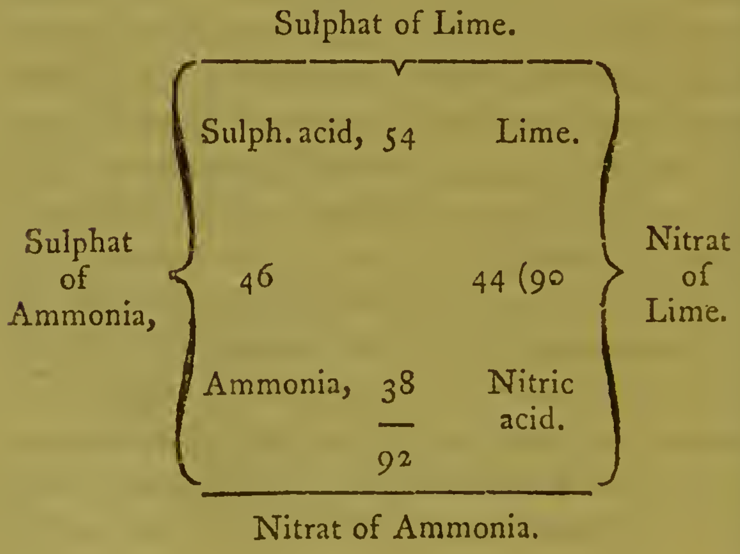
At the four corners of an imaginary square are placed
ıe four substances, so that one acid shall be diagonally
pposite to another. On the right and left side of the
uare are placed the old compounds, each on the side
 its own ingredients, and above and below are placed
ıe new compounds.

Mr Elliot improved this method of Bergman, by ad-
ing numbers expressive of the affinity of the various
ıbstances. These numbers were merely arbitrary, but
hosen so as to answer all known cases of decomposi-
on. Thus it was known that muriat of barytes and
arbonat of potass mutually decompose each other.

Therefore supposing that the affinity between the muriatic and barytes = 36; that between the same acid and potass = 32; the affinity between potass and carbonic acid = 9; and that between the same acid and barytes = 14;—we have the following formula of their decomposition:



Another instance of decomposition by compound affinities.



Such were the opinions concerning compound af-
nity which had been received by all philosophers, in
onsequence, chiefly, of the dissertation published on
e subject by Bergman. But the late experiments of
erthollet have demonstrated, that these opinions were
many respects erroneous, and that chemists had too
relessly admitted the existence of these complete de-
ompositions without sufficient examination.

Action of salts depends on their proportions.

1. It has been supposed that when two of those salts
hich mutually decompose each other are mixed toge-
er, the decomposition instantly takes place in conse-
uence of the force of affinities alone, independent of
he proportions of the ingredients. Thus when *sulphat*
f potass and *nitrat of lime* are mixed together, it was
upposed that the sulphuric acid, if present in sufficient
uantity, combines with the whole of the lime and dis-
ngages the nitric acid and the potass, which also com-
ine till the least abundant of the two be saturated.
ut if this were the case, some of the four ingredients
nust be left disengaged, as the proportions of the in-
redients of the salts formed by the four ingredients
re not such as to saturate each other. According to
Mr Kirwan's experiments, the proportions of acid and
lkali in the four following salts are as under:

Sulphat of potass	Acid	100
	Potass	121.48
Sulphat of lime	Acid	100
	Lime	70
Nitrat of potass	Acid	100
	Potass	117.7
Nitrat of lime	Acid	100
	Lime	55.7

Now let sulphat of potass and nitrat of lime be mixed together; let the quantity of sulphat of potass be such, that the acid contained in it amounts to 100; and let a more than sufficient quantity of nitrat of lime be added, to saturate the sulphuric acid with lime. It is evident that for that purpose 70 of lime must be present; and the quantity of nitric acid combined with these 70 must be 123.8. This quantity would require for saturation 145.7 of potass, but there are only 121.48 in the mixture; consequently there ought to exist in the mixture, after the mutual decomposition of the salts, a quantity of nitric acid in a state of liberty. But the fact is, that no such excess of acid exists in the mixture *. This is a sufficient proof that the decomposition does not take place in the manner that has been supposed. It may be said, indeed, that the composition of these salts may not be sufficiently known to warrant reasoning from it. But be the proportion of the ingredients what it may, still if the decomposition were absolute, as has been supposed, when mixed in any proportion whatever, except in one, some of the ingredients ought to remain disengaged; but as this does not happen either in this case or in any other, we have a right to conclude that the decomposition is not what it has been considered.

2. When two saline solutions are mixed together, either no apparent change takes place, or a precipitate is formed. Let us consider each of these cases.

When no precipitate takes place they combine.

When no precipitation takes place, the two salts no doubt combine together, and form a compound consisting of the two acids and their bases; and the degree of saturation must be the same as before mixture, because the proportions and the affinities must continue the

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* *Ann. de Chim.* xxv. 295.

ame. Hence the reason that in these cases there are never any indications of any one of the ingredients beng disengaged from the others. Hence also the reason hat when two salts are dissolved in water, they increase he solubility of each other. Their mutual affinity sering as an additional counterbalance to the cohesion of ach. Thus Vauquelin has shewn that saturated solutions of sulphat of lime, alum, and sulphat of potass, are capable of dissolving a greater proportion of comnon salt than pure water is *.

The precipitate consits of the least soluble salts.

3. When two salts may be mixed together without ny precipitation taking place, it is a proof that all the salts capable of being formed by the component parts of each are soluble. Hence the alkaline salts very rarey occasion a precipitate when mixed together, nor the earthy salts when the acid combined in each is such as to form soluble salts with all the earthy bases, as nitric acid, muriatic acid. On the other hand, when a precipitate takes place, some two of the ingredients form an insoluble compound; consequently we can easily determine before-hand whether or not a precipitate will take place. It is from this precipitation chiefly that double decompositions have been determined. It is obvious that they are occasioned not by the superiority of the affinity of the ingredients which precipitate, but by the strong tendency which these ingredients have to cohere together. The consequence of which tendency is the exclusion of the other component parts, and the precipitation of the masses as they form. It may be considered, then, as a general law, that " whenever a salt is insoluble, the two ingredients which compose it, when-

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* *Ann. de Chim.* xiii. 89.

ever they meet in a solution, precipitate in combination." For this general law we are indebted to Mr Berthollet.

Thus barytes forms an insoluble compound with sulphuric acid, phosphoric acid, oxalic acid, tartarous acid, &c. Consequently when a salt, whose base is that earth, is mixed with a salt containing any of these acids, a precipitation takes place consisting of the barytes combined with the acid. *Salts of lime* form a precipitate with oxalats, tartrites, citrats, phosphats, fluats, and sometimes with sulphats. The alkaline carbonats occasion a precipitate in all the earthy salts, because all the earthy carbonats are insoluble. Acetite of lead occasions a precipitate in sulphats, muriats, phosphats, mucites, &c. Nitrat of silver in the muriats. But it would be endless to run over all the precipitates occasioned by the mixture of salts: every person may ascertain them merely by observing what salts are insoluble.

It ought to be observed, however, that the precipitation takes place, not because the salts are insoluble in water, but because they are insoluble in the particular solution in which the precipitate appears. Now if this solution happens to be capable of dissolving any particular salt, that salt will not precipitate, even though it be insoluble in water. Hence the reason why precipitates so often disappear when there is present in the solution an excess of acid, of alkali, &c.

This law has been still further generalized by Berthollet. When different salts are mixed together, they separate either spontaneously, or on evaporation, according to the order of their solubility. Those which are insoluble precipitate immediately on the mixture,

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d those which are least soluble crystallize first when
e solution is evaporated. Potass forms with sulphu-
acid a salt much less soluble than sulphat of soda.
ence the reason why it has been supposed to have a
onger affinity for sulphuric acid, and by analogy for
ds in general, than soda: For if sulphat of soda be
xed with the greater number of the salts of potass,
phat of potass is obtained by evaporation.

But in cases where two salts are mixed together, the
ulting salts are much influenced by the proportions
the ingredients. The same salts are not obtained if
ingredients be mixed in one proportion that would
obtained if they were mixed in another proportion.
is will appear evidently from the following expe-
ments of Berthollet.

Salts Mixed.	Proportions.	Precipitate.	First Evaporation.	Second Evaporation.	Mother Water.
Nitrat of lime Sulphat of potass	1 1	Sulphat of lime	Nitrat of potass Sulphat of lime	A little sulphat of potass	Little
Ditto	1 2	Ditto	Sulphat of potass Sulphat of lime	Nitrat of potass Sulphat of potass Sulphat of lime	Very little
Ditto	2 1	Ditto	Sulphat of lime Nitrat of potass	Nitrat of potass A very little sulphat of lime.	Abundant*
Sulphat of soda Nitrat of lime	1 1	Sulphat of lime	Nitrat of soda	Nitrat of soda	Abundant †
Ditto	2 1	Ditto	Ditto	Ditto	Abundant ‡

* Composed of nitrat of lime and nitrat of potass.

† Composed of nitrat of soda and of lime.

‡ Composed probably of sulphat and nitrat of soda.

	tions.				
Sulphat of soda Nitrat of potass	1 1	Sulphat of potass A little nitrat of potass	Nitrat of potass Some sulphat of potass	Nitrat of soda Some nitrat of potass	Considerable*
Ditto	2 1	Sulphat of potass	Sulphat of potass Some nitrat of potass	Sulphat of potass Nitrat of potass Nitrat of soda	Considerable*
Nitrat of potass Muriat of lime	1 1	Nitrat of potass	Muriat of potass Some nitrat of do.		Abundant†
Ditto	1 2	Muriat of potass			Abundant†
Muriat of potass Nitrat of lime	1 1	Nitrat of potass Some muriat of do.	Muriat of potass Some nitrat of do.		Abundant ‡
Sulphat of potass Muriat of magnesia	1 1	Sulphat of potass	Sulphat of potass Muriat of do. Sulph. of pot. & mag.	Muriat of potass Sulph. of magnesia	Considerable ‡
Ditto	1 2	Ditto	Muriat of potass Sulphat of potass-and-magnesia	Ditto	Ditto

* Contained both salts.

† Composed of nitrat and muriat of lime.

‡ Composed of all the saline ingredients.

The mother water, or the liquid which remains when mixtures of salts are separated by crystallization, always contains several salts, or rather their component parts, which are prevented from crystallization by their mutual action on each other. Hence the quantity of this mother water is always the greater the more soluble the salts are; that is to say, the less disposition they have to crystallize.

CHAP IV.

OF REPULSION.

In the three preceding Chapters the properties of affinity, or of the attraction which influences the particles of bodies, have been examined. But besides attraction, matter possesses another force equally powerful, and equally obvious. and which acts as important a part in the phenomena of nature. This force is *repulsion*, which is no less interesting to the chemical philosopher than attraction, as it is often the antagonist of affinity, and is the chief agent in combustion, fulmination, detonation, evaporation, and indeed in the greater number of the most astonishing and tremendous phenomena of chemistry. It would be improper therefore to leave the general doctrines of chemistry without examining the present state of our knowledge of the laws of repulsion.

Pooofs of a repulsive force.

1. That there is a force which opposes the approach f bodies towards each other, and which tends to separate them farther from each other, is obvious from the ightest view of the phenomena of nature. When we resent the north pole of a magnet A to the same pole f another magnet B, suspended on a pivot, and at li- erty to move, the magnet B recedes as the other ap- roaches; and by following it with A at a proper di- tance, it may be made to turn round on its pivot with onsiderable velocity. In this case there is evidently ome force which opposes the approach of the north oles of A and B, and which causes the moveable mag- et to retire before the other. There is then a *repul- ion* between the two magnets, a repulsion which in- reases with the power of the magnets; and this power as been made so great, by a proper combination of nagnets, that all the force of a strong man is insufficient o make the two north poles touch each other. The ame repulsion is equally obvious on electrical bodies; nd indeed it is by means of it alone that the quantity of lectricity is measured by philosophers. If two cork alls be suspended from a body with silk threads, so as o touch each other; if we charge the body with electri- ity, the cork balls separate from each other, and stand t a distance proportional to the quantity of electricity vith which the body is charged: the balls of course re- el each other.

But it is not in electric and magnetic bodies only that repulsion is perceived. Newton has shewn, that it exists also between two pieces of glass. He found that when a convex lens was put upon a flat glass, it remains at the distance of the $\frac{1}{117}$th part of an inch, and a very considerable pressure is required to diminish this distance; nor does any force which can be applied bring them into actual mathematical contact: a force may indeed be applied sufficient to break the glasses in pieces, but it may be demonstrated that it does not diminish their distance much beyond the $\frac{1}{1000}$th part of an inch. There is therefore a force of repulsion which prevents the two glasses from touching each other. Boscovich has demonstrated, that the same repulsion exists between all hard elastic bodies. When an ivory ball sets another in motion by impinging against it, an equal quantity of its own motion is lost, as is well known Now Boscovich has shewn, that the ball at rest begins to move while the other is still at a distance.

Thus we see that there exists a repulsion between a great variety of bodies; that this repulsion acts while they are at a distance from each other; that it opposes their approach towards each other; and that it increases as the distance between them diminishes. But this force not only displays itself in bodies of considerable magnitude, it is exerted also by the particles of bodies. That the particles of *air* repel each other is evident; for a considerable force is required to keep them as near each other as we find them at the surface of the earth; and when this force is removed, they separate from each other, that is to say, the air expands. Nor is it known how far this expansion extends. Air has been artificially expanded to 3000 times its usual bulk, and doubtless at great heights in the atmosphere its expansion is still much greater than that. On the other hand, air may be forcibly condensed, that is to say, its particles may be made to approach nearer each other; but a considerable force is required to produce this effect, and this

rce increases nearly as the density: if it be removed,
e particles again separate, and the air assumes its
rmer bulk. What are the limits of this condensation
not known; but air has been forcibly compressed to
e 1000th part of its natural bulk. Thus we see that
e particles of air may be made to approach sixteen
nes nearer each other. The elasticity of air, or the
fort which it makes when compressed to resume its
rmer bulk, is evidently the consequence of a repul-
ve force which its particles exert. All gaseous fluids
ossess the same repulsive force, and are indebted to it
r their elasticity.

The particles of solid elastic bodies likewise repel
ch other; for they also, when forcibly compressed,
sume their former size, and of course their particles
pel each other. It has been demonstrated by philo-
phers, that all liquids are capable of a certain degree
f compression, and that when the compressing force
removed they resume their former bulk; conse-
uently the particles of these bodies also repel each other.
arther, it has been shown formerly, that the particles of
o body whatever are in mathematical contact; in every
ase there is a distance between them. Since this is the
ase, it is obvious that it is possible for these particles
o approach nearer each other. But if we make the
ttempt, we find that all bodies resist compression;
nany resist it so strongly, that we can produce no sen-
ible change in their size. Consequently there must be
ome force which opposes the particles of all bodies ap-
roaching nearer each other than a certain distance;
hat is to say, that the particles of all bodies at certain
listances repel each other.

2. All bodies then possess a *repulsive force* at cer-

tain distances, which opposes the diminution of these distances. The cause, or the nature of this force, is equally inscrutable with that of *attraction*, but its existence is undoubted Like attraction, it exerts itself, either at *sensible* distances or at *insensible* distances; of course the repulsions may be divided into two classes.

Sensible repulsion.

3. *Sensible* repulsion may very possibly be exerted by two bodies placed at immense distances from each other, as Boscovich has supposed, even beyond the sphere of the attraction of gravitation; but we have no proof of the existence of any such repulsion, unless the permanency of the universe, unaltered by that gravitation which ought to make the different systems gradually approach each other be considered as a proof. The only sensible repulsions with which we are acquainted take place at much smaller distances. They may be reduced to two kinds, namely, *electricity* and *magnetism*. It has been ascertained that bodies possessed of the same kind of electricity repel each other, and likewise the same magnetic poles of bodies repel each other; while, on the other hand, differently electrified bodies and the different poles of magnetic bodies attract each other. Repulsion increases, as far as has been ascertained, inversely as the square of the distance; consequently at the point of contact it is infinite.

Insensible repulsion,

4. Insensible repulsion is most conspicuous in elastic fluids, as air and the gases; but it is exhibited also by elastic bodies in general. In these, if a judgment can be formed from the experiments on air, the repulsion increases nearly at the rate of $\frac{1}{a^3}$.

5. Electric and magnetic repulsion is supposed to reside in a fluid, or rather in two fluids, the particles of

ich of which repel those which are similar to them-
elves, but attract the particles of the other fluid. In-
nsible repulsion is intimately connected with caloric;
body which has been already examined, and which
eems to consist of particles that mutually repel each
ther. It is well known that the elasticity of air and
ll other gaseous bodies is increased by heat; or more
ccurately, that the repulsion between the particles of
ir, the distance remaining the same, increases with the
emperature, so that at last it becomes so great as to
vercome every obstacle which can be opposed to it.
)n the other hand, this repulsion diminishes with the
emperature; the consequence of which is, that the ex-
ernal pressure remaining the same, the air is unable to
esist it as usual, and of course its particles approach
earer each other.

Either inherent in all matter,

6. Insensible repulsion may either be a force inherent
n the particles of bodies, or it may belong exclusively
o some particular body combined with these particles.
The first of these hypotheses seems to have been adopt-
d by Newton. In the 31st query at the end of his
)ptics, he gives us his opinion concerning the constitu-
ion of nature. He supposes that the primitive particles
f matter are similar, extremely hard and dense, and
hat by their combination they form all the different
odies with which we are acquainted. That these par-
icles have been endowed by their Creator with a cer-
ain force, in consequence of which they act mutually
n each other, and occasion all the phenomena of the
material world; that this force changes with the dis-
ance of the particles, not only its intensity, but also its
nature; that the particles when at one distance attract,
ut when this distance is increased or diminished to

a certain extent, the attraction vanishes and repulsion succeeds it.

The ideas of this illustrious philosopher were only delivered in general terms, without applying them to the explanation of particular phenomena. But in 1758, Boscovich published his *Theoria Philosophiæ Naturalis*, in which he gives a detailed explanation of the economy of nature, in principles fundamentally the same with those of Newton, but new modelled with so much ingenuity, and supported by such excellent metaphysical and mathematical reasoning, that he made them entirely his own, and deservedly acquired the reputation of one of the greatest philosophers of the age. According to him, the particles of matter, or the atoms of which all bodies are composed, are mere mathematical points, destitute of extension and magnitude, but capable of acting on each other with a force which differs in intensity and in kind according to the distance. At sensible distances the force is attractive, and diminishes inversely as the square of the distance. At the smallest distances the force is repulsive; it increases as the distance diminishes, and at last becomes infinite or insuperable; so that absolute contact of course is impossible. The space between this last repulsive distance and sensible distances is divided into an indefinite number of parts, alternately attractive and repulsive Thus let us suppose it divided into ten such parts: while the particles are at any distance between 9 and 10, that is to say, greater than 9 but less than 10, they repel; between 8 and 9 they attract; between 7 and 8 they repel; between 6 and 7 they attract, and so on. At the distances 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, which are the limits between these attracting and repelling spaces, they neither attract r repel. The happy explanation which this theory nables Boscovich to give of the greater number of na- ral phenomena is really astonishing; but there are enomena which refuse to submit themselves to this genious theory; particulary those numerous changes perated on bodies by the action of caloric.

Or confined to a peculiar substance.

7. Other philosophers have supposed that repulsion not a property inherent in all matter, but confined to peculiar substance which has been generally considered caloric. According to this hypothesis, there are two inds of matter, one whose particles attract, another hose particles repel. Let us call the first *cohesive mat- r* and the other *caloric;* and let us suppose also, what ust be the case, that cohesive matter and caloric at- act each other with a force which varies as some ower or function of the distance. In that case we have, . The particles of cohesive matter attracting each other, $\frac{1}{d^x} + a$. 2. The particles of cohesive matter attrac- ng caloric, as $\frac{1}{d^y} + b$. 3. The particles of caloric re- elling each other, as $\frac{1}{d^z} + c$. To make the case as mple as possible, let us suppose a, b, and c, each $= 0$. he simplest inspection of the phenomena of nature is ufficient to convince us, that of the three quantities y, x, d z, x must be the least, and that y and z cannot differ uch from each other. In order to form something e a precise notion of the subject, let us suppose $x = 2$ d y and z each $= 3$.

Every particle of adhesive matter must be combined ith a particle of caloric, and these two must be in ac- al mathematical contact; for without this supposition the phenomena of nature would be inexplicable. Every particle of adhesive matter may also be surrounded with an atmosphere of caloric, which atmospheres will necessarily diminish and alter entirely in the arrangement of the particles which compose them as the two particles of adhesive matter approach each other.

Let us suppose two particles of adhesive matter combined each with a particle of caloric acting upon each other at different distances. The variation of the different attractions and repulsions may be represented by fig. 35. Let the line AB represent the different distances of the two compound particles from each other; one of the particles remaining stationary in A, while the other is moving towards B. The ordinates $m\,b$, $n\,c$, $o\,d$, $p\,e$, $q\,f$, $r\,g$, $s\,h$, $t\,i$, $u\,k$, $x\,l$, represent the attractive forces when the second particle is at the points m, n, o, p, q, r, s, t, u, x, respectively; and the ordinates $m\,b'$, $n\,c'$, $o\,d'$, &c. represent the repulsive forces at the same points. The curves $c\ d\ e\ f\ g\ h\ i\ k\ l$, and $c'\ d'\ e'\ f'\ g'\ h'\ i'\ k'\ l'$, drawn through the extremities of these ordinates, are the curves of repulsion and attraction. The properties of these curves have been investigated by mathematicians; but it is unnecessary to have recourse to their investigation, as a bare inspection of the figure is sufficient to demonstrate that it is altogether irreconcileable with the phenomena of nature: For since the ordinates of the repulsive curve diminish at a greater rate than those of the attractive, at some particular distance from A they will be equal to each other. Let us suppose them to be equal at r, and let $A\,r = 6$, and $r\,g$ or $r\,g' = 1$. Let $A\,m = 1$, $A\,n = 2$, $A\,o = 3$, $A\,p = 4$, &c. Then at the points m, n, o, p, &c.

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e have the repulsive and attractive ordinates equal arly to the following numbers :

	m	*n*	*o*	*p*	*q*	*r*	*s*	*t*	*u*	*x*
puls.	216 00	27.00	7.90	3.20	1.70	1.00	6.2	4.2	2.9	2.1
tract.	39.60	9.00	4.00	2.20	1.40	1.00	7.3	5.6	4.4	3.6

ow as these forces are opposed to each other, they rtly destroy each other ; therefore to find the absote force by which the two compound particles are relled or attracted, while the second compound particle in the points *m*, *n*, *o*, &c. we have only to take the fference between the attracting and repelling ordinates these points. This gives us the following result :

	m	*n*	*o*	*p*	*q*	*r*	*s*	*t*	*u*	*x*
ep.	176.40	18.00	3.90	1.00	3.00	0				
ttr.						0	0.11	0.14	0.15	0.15

ie point *r* is evidently a point of cohesion ; as the o particles, when at the distance denoted by it, are ither attracted nor repelled. But the attractions which llow are totally incompatible with the phenomena : r, instead of diminishing as $\frac{1}{d^2}$, they diminish at an comparably slower rate. The same remark applies to repulsions.

We are absolutely certain, then, that *x* and *y* are not 2 and 3. They must be such, that the difference been $\frac{1}{d^x}$ and $\frac{1}{d^y}$ is a square ; that is to say, we must ve $\frac{1}{d^y}-\frac{1}{d^x}=\frac{1}{d^2}$, for that alone corresponds with the enomena. The fact is, if the above supposition, that ere are two kinds of matter, one repelling and anoer attracting, be adopted, it is obvious that the rate at iich we see the attractions and repulsions of bodies to vary, is only the difference between the respective forces which the particles of matter possess. Of course we cannot ascertain these forces except indirectly. Thus if we suppose $x = 3$, and $y = 5$, and that the two forces are equal as before at the point r; that is, let rg or $rg' = a$, then the attractions and repulsions in the different points will be as follows:

	m	*n*	*o*	*p*	*q*	*r*	*s*	*t*	*u*	*x*
Rep.	$\frac{6^5}{1^5}a$	$\frac{6^5}{2^5}a$	$\frac{6^5}{3^5}a$	$\frac{6^5}{4^5}a$	$\frac{6^5}{5^5}a$	a	$\frac{6^5}{7^5}a$	$\frac{6^5}{8^5}a$	$\frac{6^5}{9^5}a$	$\frac{6^5}{10^5}a$
Attr.	$\frac{6^3}{1^3}a$	$\frac{6^3}{2^3}a$	$\frac{6^3}{3^3}a$	$\frac{6^3}{4^3}a$	$\frac{6^3}{5^3}a$	a	$\frac{6^3}{7^3}a$	$\frac{6^3}{8^3}a$	$\frac{6^3}{9^3}a$	$\frac{6^3}{10^3}a$
Rep.	$\frac{6^2}{1^2}a$	$\frac{6^2}{2^2}a$	$\frac{6^2}{3^2}a$	$\frac{6^2}{4^2}a$	$\frac{6^2}{5^2}a$	0				
Attr.						0	$\frac{6^2}{7^2}a$	$\frac{6^2}{8^2}a$	$\frac{6^2}{9^2}a$	$\frac{6^2}{10^2}a$

Here the rate of variation is always as $\frac{1}{d^2}$. The attractive and repulsive curves would assume a very different form from those in the figure. But it is needless to examine the subject farther, as it would be necessary to shew, before admitting the hypothesis, that the repulsion varies at the rate of $\frac{1}{d^2}$. If this could be proved, the greater number of the phenomena of nature could be explained, upon this hypothesis, with the same facility as that of Boscovich; and it would have the additional advantage of not assuming the existence of any force whose action is not actually demonstrated by the phenomena. It is obvious that the changes from attractions to repulsion, when more than one such change appears in consequence of varying the distance between bodies, may be accounted for by supposing that part of the caloric is driven off by the approach of the bodies.

Chap. IV.

8. Before leaving this subject, it will be worth while to shew, by an example, that the repulsion between the particles of caloric often acts as a real chemical force, and that it affords a key to explain several phenomena which at first sight appear nearly contradictory. Why do bodies require different temperatures in order to unite? and Why does the presence of caloric, in many cases, favour, or rather produce, union, while it prevents or destroys it in others?

Some substances, phosphorus for instance, combine with oxygen at the common temperature of the atmosphere; others, as carbon, require a higher temperature; and others, as hydrogen and azotic gas, do not combine except at a very high temperature. To what are these differences owing?

It is evident, that whatever diminishes the cohesion which exists between the particles of any body, must tend to facilitate their chemical union with the particles of other bodies: this is the reason that bodies combine more easily when held in solution by water, or when they have been previously reduced to a fine powder. Now caloric possesses the property of diminishing cohesion. And one reason why some bodies require a high temperature to cause them to combine is, that at a low temperature the attraction of *cohesion* is in them superior to that of affinity; accordingly, it becomes necessary to weaken that attraction by caloric till it becomes inferior to that of affinity. The quantity of caloric necessary for this purpose must vary according to the strength of the cohesion and of the affinity; it must be inversely as the affinity, and directly as the cohesion. Wherefore, if we knew precisely the force of the cohesion between the particles of any body, and of the affinity between the particles of that body and of any other, we could easily reduce the temperature necessary to calculation.

That caloric or temperature acts in this manner, cannot be doubted, if we consider that other methods of diminishing the attraction of cohesion may be substituted for it with success. A large lump of charcoal, for instance, will not unite with oxygen at so low a temperature as the same charcoal will do when reduced to a very fine powder; and charcoal will combine with oxygen at a still lower temperature, if it be reduced to its integrant particles, by precipitating it from alcohol, as Dr Priestley did by passing the alcohol through red hot copper. And to shew that there is nothing in the nature of oxygen and carbon which renders a high temperature necessary for their union, if they be presented to each other in different circumstances, they combine at the common temperature of the atmosphere; for if nitric acid, at the temperature of 60°, be poured upon charcoal powder, well dried in a close crucible, the charcoal takes fire, owing to its combining with the oxygen of the acid *: And in some other situations, carbon is so completely divided that it is capable of combining with the oxygen of the atmosphere, or, which is the same thing, of catching fire at the common temperature: this seems to be the case with it in those pyrophori that are formed by distilling to dryness several of the neutral salts which contain acetous acid †. These observations are sufficient to shew, that

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* Proust and Morveau, *Encyc. Method. Chim.* i. 474.

† Morveau, ibid.

Chap. IV.

ıloric is in many cases necessary in order to diminish ıe attraction of *cohesion*.

But there is a difficulty still remaining: How comes that certain bodies will combine with oxygen without e assistance of any foreign heat, provided the combinaɔn be once begun, though a quantity of caloric is :cessary to begin the combination? and that other ɔdies require to be surrounded by a great quantity of loric during the whole time of their combining with ygen? Alcohol, for instance, if once kindled, burns l it is quite consumed; and this is the case with oils ;o, provided they be furnished with a wick.

We would err very much, were we to suppose that a ;h temperature is not as necessary to these substances ring the whole of their combustion as at the com:ncement of it; for Mr Monge found, on making the al, that a candle would not burn after the temperature the air around it was reduced below a certain point. All substances which continue to burn after being :e kindled are *volatile*, and they burn the easier in ɔportion to that volatility. The application of a cerı quantity of caloric to alcohol volatalizes part of it; t is to say, diminishes the attraction of its cohesion much that it combines with oxygen. The oxygen ich enters into this combination gives out as much t as volatilizes another portion of the alcohol; which ıbines with oxygen in its turn; more heat is given ; and thus the process goes on. Oils and tallow exit the very same phenomena; only as they are less ıtile, it is necessary to assist the process by means of capillary attraction of the wick, which confines the on of the caloric evolved to a small quantity of oil, thus enables it to produce the proper effect. In short, then, every substance which is capable of continuing to burn after being once kindled is volatile, or capable of being converted into vapour by the degree of heat at first applied. The reason that a live coal will not burn when suspended insulated in the air, is not, as Dr Hutton supposed*, because its *light* is dissipated; but because the coal cannot be converted into vapour by the degree of heat which it contains, and because the cohesion of its particles is too great to allow it to combine with oxygen without some such change. There are some coals, however, which contain such a quantity of bitumen that they will burn even in the situation supposed by Dr Hutton, and continue to burn, provided they be furnished with any thing to act as a wick. It is needless to add, that bitumen, like oil, is easily converted into vapour.

But this explanation, instead of removing our difficulties, has only served to increase them: For if caloric only acts by diminishing the attraction of cohesion, and converting these substances into vapour, why do not all elastic fluids combine at once without any additional caloric? why do not oxygen and hydrogen when mixed together in the state of gas, unite at once and form water? and why do not oxygen and azote which are constantly in contact in the atmosphere, unite also and form nitrous gas? Surely it cannot be the attraction of cohesion that prevents this union. And if it be ascribed to their being already combined with caloric, how comes it that an additional dose of one of the ingredients of a compound decomposes it? Surely as Mr Monge has observed, this is contrary to all the other operations in chemistry.

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* *On Light and Heat.*

That the particles of fluids are not destitute of an traction for each other, is evident from numberless cts. The particles of water draw one another after em in cases of capillary attraction; which is proba- y owing to the attraction of cohesion. It is owing the attraction of cohesion, too, that small quantities water form themselves into spheres; nor is this at- action so weak as not to be perceptible. If a small ate of glass be laid upon a globule of mercury, the obule, notwithstanding the pressure, continues to pre- rve its round figure. If the plate be gradually char- d with weights one after another, the mercury be- mes thinner and thinner, and extends itself in the rm of a plate; but as soon as the weights are re- oved, it recovers its globular figure again, and pushes the glass before it. Here we see the attraction of hesion, not only superior to gravitation, but actually ercoming an external force *. And if the work- an, after charging his plate of glass with weights, en he is forming mirrors, happen to remove these ights, the mercury which had been forced from under e glass, and was going to separate, is drawn back to place, and the glass again pushed up. Nor is the raction of cohesion confined to solids and liquids; it nnot be doubted, that it exists also in gases; at least is evident, that there subsists an attraction between ses of a different kind: for although oxygen and azo- gas are of different gravities, and ought therefore to cupy different parts of the atmosphere, we find them ways mixed together; and this can only be ascribed to attraction.

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* Morveau, *Encycl. Meth. Affinité*, p. 543.

Book III.

It seems evident, in the first place, that the affinity between the bases of the gases under consideration and oxygen is greater than their affinity for that dose of caloric which produces their elastic form; for when they are combined with oxygen, the same dose will not separate them again. Let us take hydrogen for an instance: The affinity of hydrogen is greater for oxygen than for the caloric which gives it its gaseous form; but the oxygen is also combined with caloric, and there exists an attraction of cohesion between the particles o the hydrogen gas and oxygen gas; the same attraction subsists between those of oxygen gas and hydrogen gas Now the sum of all these affinities, namely, the affinity between hydrogen and caloric, the affinity between oxygen and caloric, the cohesion of the particles of the hydrogen, and the cohesion of the particles of oxygen— is greater than the affinity between the hydrogen and oxygen; and therefore no decomposition can take place. Let the affinity between

Oxygen and caloric be	50
Hydrogen and caloric	50
Cohesion of oxygen for hydrogen	4
Cohesion of hydrogen	2
Sum of quiescent affinities	106
The affinity of oxygen and hydrogen	105

The quiescent affinities being greater than the divellent affinities, no decomposition can take place.

Let now a quantity of caloric be added to the oxygen and hydrogen gas, it has the property of expanding them, and of course of diminishing their cohesion; while its affinity for them is so small that it may be neglected. Let us suppose that it diminishes the cohesion

the oxygen 1, and of the hydrogen also 1, their cohe-
n will now be 3 and 1; and the quiescent affinities
ng only 104, while the divellent are 105; decompo-
on would of course take place, and a quantity of ca-
ic would thus be set at liberty to produce the same
cts upon the neighbouring particles.

Thus, then, caloric acts only by diminishing cohe-
n: And the reason that it is required so much in
eous substances, and in those combinations into which
gen enters, is the strong affinity of oxygen and the
er bases of the gases for caloric; for, owing to the
ulsion which exists between the particles of that sub-
substance, an effect is produced by adding large
es of it, contrary to what happens in other cases.
e more of it is accumulated, the stronger is the re-
sion between its particles; and therefore the more
verful is its tendency to fly off: and as this tendency
pposed by its affinity for the body and the cohe-
n of its particles, it must diminish both these attrac-
ns.

PART II.

CHEMICAL EXAMINATION
OF
NATURE.

Iaving, in the First Part of this Work, given a very
ll detail of the Principles of Chemistry, and a descrip-
on of the different Substances with which it is neces-
ry for the Chemist to be acquainted, I propose, in this
cond Part, to take a view of the different substances
they exist in nature, constituting the material world,
at we may ascertain how far the science of chemistry
ill contribute towards explaining their nature, and ac-
unting for the different changes which they produce on
ch other. Now the different substances of which the
aterial world, as far as we have access to it, is com-
sed, may be very conveniently arranged under the five
llowing heads:

1. The Atmosphere,
2. Waters,
3. Minerals,
4. Vegetables,
5. Animals.

These five divisions will form the subject of the five
llowing Books.

BOOK I.

OF

THE ATMOSPHERE.

Book I.

THE atmosphere is that invisible elastic fluid which surrounds the earth to an unknown height, and incloses it on all sides. It received its name from the Greeks, in consequence of the vapours which are continually mixing with it. When the chemist turns his attention to the atmosphere, there are two things which naturally engage his attention: First, to ascertain the substances of which it is composed; and, secondly, to trace the changes to which it is liable. I shall therefore divide this Book into two Chapters. In the first, I shall examine the component parts of the atmosphere; and, in the second, examine the changes to which it is liable under the title of METEOROLOGY.

CHAP. I.

COMPOSITION OF THE ATMOSPHERE.

Opinions of the ancients

NEITHER the properties nor the composition of the atosphere seem to have occupied much of the attention the ancients. Aristotle considered it as one of the ur elements, situated between the regions of *water* d *fire*, and mingled with two *exhalations*, the *dry* and e *moist*; the first of which occasioned thunder, lightng, and wind; while the second produced rain, snow, d hail. The ancients, in general, seem to have conlered the blue colour of the sky as essential to the atosphere; and several of their philosophers believed at it was the constituent principle of other bodies, or least that air and other bodies are mutually converle into each other *. But these opinions continued the state of vague conjectures till the matter was exined by the sagacity of Hales and of those philosoers who followed his illustrious career.

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* Thus Lucretius:

> Semper enim quodcunque fluit de rebus, id omne
> Aeris in magnum fertur mare: qui nisi contra
> Corpora retribuat rebus, recreetque fluenteis,
> Omnia jam resoluta forent, et in aera versa.
> Haud igitur cessat gigni de rebus et in res
> Recidere assidue, quoniam fluere omnia constat. *Lib.* v. 274.

Discoveries of the moderns.

It was not till the time of Bacon, who first taught mankind, to investigate natural phenomena, that the atmosphere began to be investigated with precision. Galileo introduced the study by pointing out its weight; a subject which was soon after investigated completely by Torricelli, Paschal, &c. Its density and elasticity were ascertained by Boyle and the Florence Academicians. Mariotte measured its dilatibility; Hooke, Newton, Boyle, Derham, pointed out its relation to light, to sound, and to electricity. Newton explained the effect produced upon it by moisture; from which Halley attempted to explain the changes in its weight indicated by the barometer. But a complete enumeration of the discoveries made upon the atmosphere in general belongs to *pneumatics;* a science which treats professedly of the mechanical properties of air

Component parts of the atmosphere.

The knowledge of the component parts of the atmosphere did not keep pace with the investigation of its mechanical properties. The opinions of the earlier chemists concerning it are too vague and absurd to merit any particular notice. Boyle, however, and his contemporaries, put it beyond doubt that the atmosphere contained two distinct substances. 1. An elastic fluid distinguished by the name of *air*. 2. Water in the state of vapour. Besides these two bodies, it was supposed that the atmosphere contained a great variety of other substances, which were continually mixing with it from the earth, and which often altered its properties, and rendered it noxious or fatal. Since the discovery of carbonic acid gas by Dr Black, it has been ascertained that this elastic fluid always constitutes a part of the atmosphere. The constituent parts of the atmosphere therefore are,

Chap. I.

1. Air,
2. Water,
3. Carbonic acid gas,
4. Unknown bodies.

These shall form the subject of the four following Sections. But before proceeding to ascertain their properties, and the proportion in which they exist in air, it will be worth while to endeavour to calculate the amount of the whole of the atmosphere which surrounds the earth. This will put it in our power to state the amount of its different constituent parts, and of course to see how far the quantities of each agree with the different chemical theories which have been maintained concerning the influence of these bodies on the different kingdoms of nature.

Its absolute quantity.

Mechanical philosophers have demonstrated, that the weight of a column of the atmosphere, whose base is an inch square, is equal to a column of mercury of the same base, and balanced by the atmosphere in the barometrical tube. Now let us suppose the mean height of the barometer to amount to nearly 30 inches. Let R denote the radius of the earth, r the height of the mercury in the barometer, π the ratio between the circumference of a circle and its diameter. The solidity of the earth is $\frac{4\pi R^3}{3}$; the solidity of the sphere composed of the earth, and a quantity of mercury surrounding it equal to the weight of the atmosphere, is $\frac{4\pi(R+r)^3}{3}$. Consequently the solidity of the hollow sphere of mercury equal to the weight of the atmosphere, is $\frac{4\pi(R+r)^3}{3}-\frac{4\pi R^3}{3}=4\pi\left(R^2r+r^2R+\frac{r^3}{3}\right)$, or, neglecting the terms containing r^2 and r^3,

$4\pi R^2 r$. This formula, by substituting for π, R^2 and r, their known values, gives us the solidity of the hollow sphere of mercury in cubic feet. But a cubic foot of mercury is nearly equal to 135,000 avoirdupois ounces. Hence the mean weight of the atmosphere amounts to about 11911163227258181818 lbs. avoirdupois.

SECT. I.

OF AIR.

Air an elastic fluid.

THE word AIR seems to have been used at first to have denoted the atmosphere in general; but philosophers afterwards restricted it to the elastic fluid, which constitutes the greatest and the most important part of the atmosphere, excluding the water and the other foreign bodies which are occasionally found mixed with it. For many years all permanently elastic fluids were considered as air, from whatever combinations they were extricated, and supposed to possess exactly the same properties with the air of the atmosphere. It is true, indeed, that Van Helmont suspected that elastic fluids possessed different properties; and that Boyle ascertained that all elastic fluids were not capable of supporting combustion like air. But it was not till the discoveries of Cavendish and Priestley had demonstrated the peculiar properties of a variety of elastic fluids, that philosophers became sensible that there existed a variety of species of them. In consequence of this discovery, the vord *air* became generic, and was applied by Priestley, nd the British and Swedish philosophers in general, to ll permanently elastic fluids, while the air of the at- nosphere was distinguished by the epithets of *common* r *atmospheric* air: but Macquer thought proper to ap- ly the term *gas*, first employed by Van Helmont, to all ermanently elastic fluids except common air, and to onfine the term *air* to this last fluid. This innovation vas scarcely necessary; but as it has now been gene- ally adopted, it will be proper to follow it. By the vord *air*, then, in this Section, I mean only common ir, or the fluid which forms by far the greatest part of he atmosphere.

The foreign bodies which are mixed or united with ir in the atmosphere are so minute in quantity compa- ed to it, that they have no very sensible influence on s properties. We may therefore consider atmospheric ir, when in its usual state of dryness, as sufficiently ure for examination.

Specific gravity.

1. Air is an elastic fluid, invisible indeed, but easily cognised by its properties. Its specific gravity, ac- ording to the experiments of Sir George Shuckburgh, hen the barometer is at 30 inches, and the thermome- er between 50° and 60°, is 0.0012, or 816 times light- than water. One hundred cubic inches of air weigh 1 grains troy.

Density.

But as air is an elastic fluid, and compressed at the urface of the earth by the whole weight of the incum- ent atmosphere, its density diminishes according to its eight above the surface of the earth. From the expe- ments of Paschal, Deluc, General Roy, &c. it has een ascertained, that the density diminishes in the ra- o of the compression. Consequently the density decreases in a geometrical progression, while the heights increase in an arithmetical progression.

Bouguer had suspected, from his observations made on the Andes, that at considerable heights the density of the air is no longer proportional to the compressing force *; but the experiments of Saussure junior, made upon Mount Rose, have demonstrated the contrary †.

Dilatability.

2. Air is dilated by heat. From the experiments of General Roy and Sir George Shuckburgh, compared with those of Trembley, &c. it appears, that at the temperature of 60°, every degree of temperature increases the bulk of air about $\frac{1}{82}$ part. But the experiments of Du Vernois and Morveau, which gives us the dilatation of air for every degree of Reaumur from 0° to 80°, have been given in a former part of this Work, and they are the most complete which have hitherto appeared.

3. The specific caloric of air, according to the experiments of Dr Crawford, is 1.79.

Colour.

4. Although the sky is well known to have a blue colour, yet it cannot be doubted that air itself is altogether colourless and invisible. The blue colour of the sky is occasioned by the vapours which are always mixed with the air, and which have the property of reflecting the blue rays more copiously than any other. This has been proved by the experiments which Saussure made with his *cyanometer* at different heights above the surface of the earth. This consisted of a circular band of paper, divided into 51 parts, each of which were painted with a different shade of blue; beginning with

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* *Mem. Par.* 1753, p. 515.

† *Jour. de Phys.* xxxvi. 98.

While Scheele was occupied with his experiments on ir, Lavoisier was assiduously employed on the same ubject, and was led by a different road to precisely the ame conclusion as Scheele. By oxidating mercury in vessel filled with common air, and heated to the boilng point of mercury, he abstracted the greater part of s oxygen gas; and by heating the red oxide thus formd, he reconverted it into mercury, while at the same me a quantity of oxygen gas was extricated. The reduum in the first experiment possessed the properties f azotic gas; but when the oxygen gas extricated from e mercury was added to it, the mixture assumed again e properties of common air. Hence he concluded at air is composed of azotic gas and oxygen; and from variety of experiments he determined the proportions be 73 parts of azotic gas and 27 parts of oxygen gas. e demonstrated, too, that when air is diminished by quid sulphurets, metals, &c. the oxygen gas which is stracted combines with the sulphurets, &c. and conrts them into acids or oxides according to their reective nature. But as all these experiments have been ready detailed in the First Part of this Work, it is unecessary to be more particular in this place.

Air composed of oxygen and azotic gas.

Air, then, is a compound of oxygen and azotic gas: ut it becomes a question of considerable consequence determine the proportion of these two ingredients, d to ascertain whether that proportion is in every se the same. Since azotic gas, one of the component rts of that fluid, cannot be separated by any substance ith which chemists are acquainted, the analysis of air n only be attempted by exposing it to the action of ose bodies which have the property of absorbing its xygen. By these bodies the oxygen gas is separated, and the azotic gas is left behind, and the proportion of oxygen may be ascertained by the diminution of bulk; which, once known, it is easy to ascertain the proportion of azotic gas, and thus to determine the exact relative quantity of the component parts.

Method of ascertaining the proportion of its component parts.

After the composition of the atmosphere was known to philosophers, it was taken for granted that the proportion of its oxygen varies in different times and in different places; and that upon this variation the purity or noxious qualities of air depended. Hence it became an object of the greatest importance to be in possession of a method of determining readily the quantity of oxygen in a given portion of air. Accordingly various methods were proposed, all of them depending upon the property which a variety of bodies possesses of absorbing the oxygen of the air, without acting upon its azot. These bodies were mixed with a certain known quantity of atmospheric air, in graduated glass vessels inverted over water, and the proportion of oxygen was determined by the diminution of bulk. These instruments received the name of *eudiometers*, because they were considered as measurers of the purity of air. The eudiometers proposed by different chemists may be reduced to five.

Eudiometer of Priestley and Fontana.

1. The first eudiometer was made in consequence of Dr Priestley's discovery, that when nitrous gas is mixed with air over water, the bulk of the mixture diminishes rapidly, in consequence of the combination of the gas with the oxygen of the air, and the absorption of the nitric acid thus formed by the water. When nitrous gas is mixed with azotic gas, no diminution at all takes place. When it is mixed with oxygen gas in proper proportions, the absorption is complete. Hence it is

vident, that in all cases of a mixture of these two ases, the diminution will be proportional to the quanity of the oxygen. Of course it will indicate the proortion of oxygen in air; and by mixing it with diffeent portions of air, it will indicate the different quanities of oxygen which they contain, provided the comonent parts of air be susceptible of variation. Dr 'riestley's method was to mix together equal bulks of ir and nitrous gas in a low jar, and then to transfer he mixture into a narrow graduated glass tube about hree feet long, in order to measure the diminution of bulk. He expressed this diminution by the number of hundred parts remaining. Thus, suppose he had nixed together equal parts of nitrous gas and air, the um total of this mixture was 200 (or 2.00): suppose he residuum when measured in the graduated tube to mount to 104 (or 1.04), and of course that 96 parts of the whole had disappeared, he denoted the purity of he air thus tried by 104. A more convenient instrunent was invented by Dr Falconer of Bath; and Fonana greatly improved this method of measuring the ourity of air. A description of his eudiometer was pubished by Ingenhoutz in the first volume of his Experinents; it was still farther improved by Cavendish in 1783*; and Humbolt has lately made a very laborious set of experiments in order to bring it to a state of complete accuracy. But after all the exertions of these philosophers, the method of analysing air by means of nitrous gas is liable to so many anomalies, that it cannot be depended on.

Priestley and Fontana have proved, that the way of

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* *Phil. Trans.* lxxiii. 107.

mixing the two airs occasions a great difference in the result; the figure of the vessels is equally important, and so is the water over which the mixture is made. And even when all these things are the same, impurity of the nitrous gas may occasion the most enormous differences in the results.

Humbolt has shown, that the nitrous gas ought to be prepared by means of nitric acid of the density 1.170; when a much stronger or weaker acid is employed, the gas produced is always contaminated with a great proportion of azotic gas. He has pointed out the solution of sulphat of iron, as proper to ascertain the purity of the nitrous gas employed, by absorbing the nitrous gas and leaving the azotic gas or other foreign gases. He has shown, that when nitrous gas of the same degree of purity is made to mix very slowly with air, the vessel being carefully agitated during the mixture, the results, provided the experiment be performed with address, correspond with each other. And he has made it probable, that when equal quantities of air and nitrous gas, so pure as to contain only about 0.1 of azotic gas mixed with it, are agitated together slowly over water, the diminution divided by 3.55 gives the quantity of oxygen contained in the air examined. But notwithstanding the ingenuity of his experiments, the anomalies attending this method are still so great as not to render it susceptible of accuracy For that reason I think it unnecessary to give a particular description of the different eudiometers invented to ascertain the purity of air by means of nitrous gas. The result of the numerous experiments which have been made with nitrous gas is, that the proportion of oxygen in atmospheric air varies in different places and at different times. The mini-num is about 0.22, the maximum about 0.30; consequently if this method of analysing air is to be depended on, we must consider that fluid, not as a permanent chemical compound, but as a body subjected to all the variations to which accidental mixtures are liable.

Eudiometer of Volta.

2. The second kind of eudiometer was proposed by Volta. The substance employed by that philosopher to separate the oxygen from the air was hydrogen gas. His method was to mix given proportions of the air to be examined and hydrogen gas in a graduated glass tube; to fire the mixture by an electric spark; and to judge of the purity of the air by the bulk of the residuum. But this method is not susceptible of so great a degree of accuracy as the preceding, when the object is to ascertain the precise quantity of oxygen gas in a given bulk of air. For if too little hydrogen gas be mixed with the air, not only the whole of the oxygen will not be abstracted, but a portion of the azot will disappear in consequence of the formation of nitric acid. On the other hand, if too much hydrogen be added, part of it will remain after the firing of the mixture, and increase the bulk of the residuum. Volta's eudiometer, then, though it may have its uses, is scarcely susceptible of giving us the analysis of air.

Eudiometer of Scheele

3. For the third kind of eudiometer, we are indebted to Scheele. It is merely a graduated glass vessel, containing a given quantity of air exposed to newly prepared liquid alkaline or earthy sulphurets, or to a mixture of iron-filings and sulphur, formed into a paste with water. These substances absorb the whole of the oxygen of the air, which converts a portion of the sulphur into an acid. The oxygen contained in the air

thus examined, is judged of by the diminution of bulk which the air has undergone. This method is not only exceedingly simple, but it requires very little address, and yet is susceptible of as great accuracy as any other whatever. The only objection to which it is liable is its slowness; for when the quantity of air operated on is considerable, several days elapse before the diminution has reached its maximum.

Improved by De Marti.

But this objection has been completely obviated by Mr De Marti, who has brought Scheele's eudiometer to a state of perfection. He found that a mixture of iron filings and sulphur does not answer well, because it emits a small quantity of hydrogen gas, evolved by the action of the sulphuric acid formed by the absorption of the oxygen of the air upon the iron; but the hydrogenated sulphurets, formed by boiling together sulphur and liquid potass or lime-water, answered the purpose perfectly. These substances, indeed, when newly prepared, have the property of absorbing a small portion of azotic gas; but they lose this property when saturated with that gas, which is easily affected by agitating them for a few minutes with a small portion of atmospheric air. His apparatus is merely a glass tube, ten inches long, and rather less than half an inch in diameter, open at one end, and hermetically sealed at the other. The close end is divided into 100 equal parts, having an interval of one line between each division. The use of this tube is to measure the portion of air to be employed in the experiment. The tube is filled with water; and by allowing the water to run out gradually while the tube is inverted, and the open end kept shut with the finger, the graduated part is exactly filled with air. These hundred parts of air are introuced into a glass bottle filled with liquid sulphuret of ime previously saturated with azotic gas, and capable f holding from two to four times the bulk of the air troduced. The bottle is then to be corked with a round glass stopper, and agitated for five minutes. Afer this the cork is to be withdrawn while the mouth f the phial is under water; and for the greater secuity, it may be corked and agitated again. After this, he air is to be again transferred to the graduated glass ube, in order to ascertain the diminution of its bulk*.

Air examined by this process, suffers precisely the ame diminution in whatever circumstances the expeiments are made: no variation is observed whether he wind be high or low, or from what quarter soever t blows; whether the air tried be moist or dry, hot or old; whether the barometer be high or low. Neiher the season of the year, nor the situation of the lace, its vicinity to the sea, to marshes, or to mounains, make any difference. Mr De Marti found the liminution always between 0.21 and 0.23. Hence we nay conclude that air is composed of

0.78 azotic gas
0.22 oxygen gas

1.00

Scheele indeed found, that the absorption amounted to 0.27*; but that was because he neglected to saturate his sulphuret with azotic gas; for when the portion of azotic gas which must have been absorbed, and which has been indicated by De Marti, is subtracted, the portion of oxygen in air, as indicated by his experiments,

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* *Jour. de Phys.* lii. 176.

* Scheele, ii. 1.

is reduced very neaaly to 0.22. The trifling variations perceptible in his experiments were no doubt owing to the quantities of the mixture of sulphur and iron, by which he abstracted the oxygen, not being exactly the same at different times; the consequence of which would be an unequal absorption of azotic gas.

Eudiometer of Berthollet.

4. In the fourth kind of eudiometer, the abstraction of the oxygen of air is accomplished by means of phosphorus. This eudiometer was first proposed by Achard [*]. It was considerably improved by Reboul [†], and by Seguin and Lavoisier [‡]; but Berthollet [§] has lately brought it to a state of perfection, as it is equally simple with the eudiometer of De Marti, and scarcely inferior to it in precision.

Instead of the rapid combustion of phosphorus, this last philosopher has substituted its spontaneous combustion, which absorbs the oxygen of air completely; and when the quantity of air operated on is small, the process is over in a short time. The whole apparatus consists in a narrow graduated tube of glass containing the air to be examined, into which is introduced a cylinder of phosphorus fixed upon a glass rod, while the tube stands inverted over water. The phosphorus should be so long as to traverse nearly the whole of the air. Immediately white vapours rise from the phosphorus and fill the tube. These continue till the whole of the oxygen combines with phosphorus. They consist of phosphorous acid, which falls by its weight to the bottom of the vessel, and is absorbed by

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[*] *Jour. de Phys.* 1784, vol. i.

[†] *Ann. de Chim.* xiii. 38.

[‡] Ibid. ix. 293.

[§] Ibid. xxxiv. 73. and *Jour. de l'Ecole Polytechn.* I. iii. 274.

ıe water. The residuum is merely the azotic gas of ıe air, holding a portion of phosphorus in solution. ertholl et has ascertained, that by this foreign body its ılk is increased $\frac{1}{40}$th part. Consequently the bulk of ıe residuum, diminished by $\frac{1}{40}$, gives us the bulk of ıe azotic gas of the air examined; which bulk subacted from the original mass of air, gives us the proortion of oxygen gas contained in it.

All the different experiments which have been made y means of this eudiometer agree precisely in their reılt, and indicate that the proportions of the ingreients of air are always the same; namely, about 0.22 arts of oxygen gas, and 0.78 of azotic gas. Bertholt found these proportions in Egypt and in France, and I ave found them constantly in Edinburgh in all the difrent seasons of the year. Thus we see that the anaysis of air, by means of phosphorus, agrees precisely vith its analysis by means of hydrogenated sulphurets.

Eudiometer of Davy.

5. The fifth eudiometer has been lately proposed by Ir Davy. In it the substance used to absorb the oxyen from air is a solution of sulphat or muriat of iron n water, and impregnated with nitrous gas. A small raduated glass tube, filled with the air to be examined, plunged into the nitrous solution, and moved a little ackwards and forwards. The whole of the oxygen is bsorbed in a few minutes. The state of greatest aborption ought to be marked, as the mixture afterwards mits a little gas which would alter the result. By neans of this and the two preceding eudiometers, Mr avy examined the air at Bristol, and found it always o contain about 0.21 of oxygen. Air sent to Dr Bedloes from the coast of Guinea gave exactly the same

result. This eudiometer, then, corresponds exactly with the two last *.

Method of ascertaining the density of the air operated on.

In all these different methods of analysing air, it is necessary to operate on air of a determinate density, and to take care that the residuum be neither more condensed nor dilated than the air was when first operated on. If these things are not attended to, no dependance whatever can be placed upon the result of the experiments, how carefully soever they may have been performed. Now there are three things which alter the volume of air and other elastic fluids: 1. A change in the height of the barometer. 2. An increase or diminution of their quantity; the vessel in which they are contained remaining the same, and standing in the same quantity of water or mercury. 3. A change in the temperature of the air.

How to reduce air to a given barometrical pressure.

1. The density of air and other elastic fluids is always proportional to the compressing force. Now they are compressed by the weight of the atmosphere, which is measured by the barometer. If that weight diminishes, their density diminishes in proportion, and of course their bulk increases: if the weight of the atmosphere increases, their density increases, and their bulk diminishes in the same proportion. Consequently if the height of the barometer varies during an experiment, the bulk of the residuum will not be the same that it would have been if no such change had taken place. We will therefore commit an error unless we reduce the bulk of the residuum to what it would have been if no such alteration had taken place. This is easily done by a very simple formula.

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* *Phil. Mag.* x. 56.

It has been ascertained by philosophers, that the vo- mes of air are always inversely as the compressing rces. Therefore let m be the height of the barome- r at the commencement of an experiment, n its height ı the end; v the volume of the gas when the barome- r is at n, and x its volume supposing the barometer at . We have $n : m :: x : v$. Consequently $x = \frac{n\,v}{m}$ o that to find the volume required, we have only to ıultiply the volume obtained by the actual height of ıe barometer, and divide by the height of the barome- r at which we want to know the volume: And, in eneral, to reduce a volume of air to the volume it ould occupy, supposing the barometer at 30 inches, e have only to use the above formula, substituting 30 ı place of m.

To reduce it to the density of external air.

2. When air is confined in a jar standing over water r mercury, its density is not the same with that of the tmosphere, unless its lower surface in the jar be ex- ctly level with the surface of the liquid in the tub in hich it stands. Let A (fig. 36.) be a jar containing air, nd BC the surface of the water or mercury in the tub in hich the jar is inverted; the air within the jar is not f the same density with the external air, unless it fills xactly that part of the jar above BC. If it fill only hat part of it between A and D while the water or nercury rises to D, the air will be more dilated than he external air, because it is compressed only by the veight of the atmosphere, diminished by the colnmn of nercury or water D m. On the other hand, if the wa- er or mercury only rise in the jar to E, the air within t will be denser than the external, because it is com- pressed by the weight of the atmosphere, and also by

the column of water or air m E. It is proper therefore in all cases, to bring the lower surface of the air in the jar to the same level with the surface of the water o mercury in the trough. But in eudiometrical experiments this is often impossible; because part of the air being absorbed, though the water or mercury over which it stands at first only rose to m, yet the absorption which takes place occasions it to rise to some line D above m. Hence the air which remains after the experiment is in a state of dilatation, and must be reduced by calculation to the volume which it would occupy were it in the same state of compression as at the commencement of the experiment. This is easily done by the following formula.

Let us suppose the experiment is made over mercury. Let H be the height of the barometer at the commencement of the experiment, h the length of the column of mercury m D, v the volume of the air in AD, and x the volume required, or the volume which the air would have supposing D to coincide with m. Then we have $H : H - h :: v : x$. And $x = \frac{(H - h)\, v}{H}$. Thus let H be 30 inches, $h = 5$ inches, and $v = 200$ cubic inches; then $x = 166\frac{2}{3}$ cubic inches; so that without this correction the error would amount to no less than $33\frac{1}{3}$ cubic inches, or about the sixth part of the whole. When the experiment is made over water, the same formula applies; only in that case H must be multiplied by 13.6, because a column of water 13.6 times longer than mercury is necessary to produce the same pressure. In that case, supposing the numbers the same as before, x would be $= 197\frac{1}{2}$; so that the error er water is only 2½ inches, or the 80th part of the iole.

Allowance for temperature.

3. A change in the temperature may be more easily arded against in eudiometrical experiments, as they usually made within doors: but when it does hap-n, it occasions an alteration in the volume of the air; increase of temperature dilating it, and a diminution temperature occasioning a condensation. This error ıy be easily corrected in air and all other gases, by reasing or diminishing their apparent bulk for every gree of change in the thermometer, according to the ıble of the dilations of the gases formerly given *.

Composition of air.

We may consider it as established by experiment, at air is composed of 0.22 of oxygen gas, and 0.78 of otic gas by bulk. But as the weight of these two ses is not exactly the same, the proportion of the component parts by weight will differ a little: For as the ecific gravity of oxygen gas is to that of azotic gas as 5 : 115, it follows that 100 parts of air are composed weight of about

74 azotic gas
26 oxygen gas

100

ıich differs very little from the determination of La-isier, provided that philosopher meant to denote by numbers the weight and not the volume of the component parts of air.

Air a chemical compound.

7. Having thus ascertained the nature and the pro-rtion of the component parts of air, it remains only enquire in what manner these component parts are ited. Are they merely mixed together mechanically,

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* Volume I. p. 269.

or are they combined chemically? Is air a mechanical mixture or a chemical compound? Philosophers seem at first to have adopted the former of these opinions, if we except Scheele, who always considered air as a chemical compound. But the supposition that air is a mechanical mixture, by no means agrees with the phenomena which it exhibits. If the two gases were only mixed together as their specific gravity is different, it is scarcely possible that they would be uniformly mixed in every part of the atmosphere. Even Mr Dalton's ingenious supposition, that they neither attract nor repel each other, would not account for this equal distribution: for undoubtedly, on that supposition, they would arrange themselves according to their specific gravity. Since therefore air is in all places composed of the same ingredients, exactly in the same proportions, it follows that its component parts are not only mixed, but actually combined. When substances differing in specific gravity combine together, the specific gravity of the compound is usually greater than the mean. This holds also with respect to air. The specific gravity, by calculation, amounts only to 0.00119, whereas it actually is 0.0012; a difference by no means inconsiderable. But perhaps the specific gravity of azotic and oxygen gas can scarcely be considered as known with such precision as to entitle us to draw any consequence from this difference.

But the difference between air and a mere mixture of its two component parts has been demonstrated by the experiments of Morozzo and Humbolt. The artificial mixture is much more diminished by nitrous gas than air, even when the mixture contains less oxygen *. It

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* Humbolt, *Ann. de Chim.* xxviii. 162.

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pports flame better and longer, and animals do not e in it the same time that they do in an equal por- n of air, but longer †.

We must therefore consider air as a chemical com- und. Hence the reason that it is in all cases the ne, notwithstanding the numerous decomposing pro- sses to which it is subjected. The breathing of ani- ls, combustion, and a thousand other operations, are nstantly abstracting its oxygen, and decomposing it. e air thus decomposed or vitiated no doubt ascends the atmosphere, and is again, by some unknown pro- ss or other, reconverted into atmospherical air. But e nature of these changes is at present concealed un- r an impenetrable veil.

SECT. II.

OF WATER.

Water of the atmosphere

THAT the atmosphere contains water, has been always nown. The rain and dew which so often precipitate om it, the clouds and fogs with which it is often ob- ured, and which deposite moisture on all bodies ex- sed to them, have demonstrated its existence in eve- age. Even when the atmosphere is perfectly trans- rent, water may be extracted from it in abundance y certain substances. Thus if concentrated sulphuric id be exposed to air, it gradually attracts so much

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† Morozzo, *Jour. de Phys.* xlvii. 203.

Detected by the hygrometer.

moisture, that its weight is increased more than three times: it is converted into diluted acid, from which the water may be separated by distillation. Substances which have the property of abstracting water from the atmosphere, have received the epithet of *hygroscopic*, because they point out the presence of that water. Sulphuric acid, the fixed alkalies, muriat of lime, nitrat of lime, and in general all deliquescent salts, possess this property. The greater number of animal and vegetable bodies likewise possess it. Many of them take water from moist air, but give it out again to the air when dry. These bodies augment in bulk when they receive moisture, and diminish again when they part with it. Hence some of them have been employed as *hygrometers* or measurers of the quantity of moisture contained in the air around them. This they do by means of the increase or diminution of their length, occasioned by the addition or abstraction of moisture. This change of length is precisely marked by means of an index. The most ingenious and accurate hygrometers are those of Saussure and Deluc. In the first, the substance employed to mark the moisture is a human hair, which by its contractions and dilatations is made to turn round an index. In the second, instead of a hair, a very fine thin slip of whalebone is employed. The scale is divided into 100°. The beginning of the scale indicates extreme dryness, the end of it indicates extreme moisture. It is graduated by placing it first in air made as dry as possible by means of salts, and afterwards in air saturated with moisture. This gives the extremes of the scale, and the interval between them is divided into 100 equal parts.

Since it cannot be doubted that the atmosphere al-

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ys contains water, there are only two points which
main to be investigated: 1. The quantity of water
ich a given bulk contains; 2. The state in which
t water exists in air.

Quantity of water in air.

Many attempts had been made to measure the quan-
y of water contained in air, but Saussure was the
st who attained any thing like precision. This inge-
us philosopher has shewn, in his Hygrometrical Es-
s, that an English cubic foot of air, when saturated
th water at the temperature of 66°, contains only
out 8 grains troy of that liquid, or about $\frac{1}{67}$th of its
ight. At the temperature of 32°, a cubic foot of
can contain only 4 grains, or $\frac{1}{134}$th part of its weight.
e quantity of water which a cubic foot of air can
ntain, increases 0.1109 grains for every additional
gree of heat. The following TABLE exhibits the dif-
ent quantities of water in grains contained in a cubic
t of air at different degrees of temperature, corre-
onding to the different degrees of Saussure's hygro-
eter. For this Table, by far the most perfect which
s hitherto appeared, we are indebed to the same ce-
rated philosopher.

Degrees of hygrometer.	TEMPERATURE *.				
	10°	21°	32°	43°	54°
40°	0.8971	1.1067	1.3653	1.6843	2.0779
45	1.0676	1.3171	1.6248	2.0045	2.4729
50	1.2197	1.5047	1.8563	2.2900	2.8251
55	1.4116	1.7414	2.1453	2.6503	3.2696
60	1.6411	2.0246	2.4976	3.0590	3.7737
65	1.9204	2.3691	2.9226	3.6055	4.4480
70	2.2277	2.7482	3.3903	4.1824	5.1596
75	2.5215	3.1107	3.8375	4.7342	5.8404
80	2.8155	3.4734	4.2850	5.2862	6.5213
85	3.1095	3.8361	4.7 24	5.8381	7.2022
90	3.4035	4.1987	5.1797	6.3902	7.8 31
95	3.6946	4.557	5.6227	6.942	8.5620
98	3.8739	4.7790	5.8956	7.2731	8.9725

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* In this Table the cubic foot of air and the grains of water contained in it are both left in the original French measures as calculated by Saussure. The relative proportion being alone of importance, I did not think it worth while to reduce them to our standard: But in order to convert the grains in the Table into the number of grains troy contained in an English cubic foot of air, it is only necessary to multiply them by 0.6773181.

Degrees of Hygrometer.	TEMPERATURE.			
	60°	77°	88°	100°
40°	2.5634	3.1625	3.9016	4.8134
45	2.9952	3.6952	4.5588	5.6242
50	3.4852	4.2997	5.3045	6.5442
55	4.0335	4.9761	6.1390	7.5737
60	4.6554	5.7434	7.0856	8.7415
65	5.4873	6.7697	8.3518	10.3036
70	6.3651	7.8526	9.6878	11.9518
75	7.2050	8.8888	10.9661	13.5289
80	8.0450	9.9251	12.2446	15.1062
85	8.8850	10.9614	13.5231	16.6834
90	9.7250	11.9977	14.8016	18.2607
95	10.5650	13.034	16.0800	19.8379
98	11.0690	13.6558	16.8472	20.7844

The quantity of water which air is capable of con-
ning diminishes also as the density of that air dimi-
hes. Saussure ascertained that air, rarefied so as
y to be able to support a column of mercury 0.222
h long, does not contain when saturated with mois-
e more than the 20th part of what air is capable of
taining under the pressure of 28 8 inches of mercu-
The following Table, drawn up by Mr Saussure,
icates the proportional quantity of water which a cu-

bic foot of air is capable of containing at different densities; the density as usual being indicated by the length of the column of mercury which it is capable of balancing.

Height of Barometer.	Quantity of Water.
28.8 inches	1.0000
25.18	0.9528
21.58	0.8899
18.38	0.8264
14.29	0.7629
10.79	0.6887
7.19	0.6230
3.59	0.4311
0.22	0.0485

Such are the quantities of water contained in air in different circumstances while that fluid retains its transparence. But as the method which Saussure took to separate all the moisture from air was to expose it to the action of very dry potass, it may be questioned whether by this process he was able to free the air altogether from moisture; and if not, it is a point of considerable consequence to determine if possible the quantity which still remains after the potass ceases to act.

Whether water be essential to air.

Some philosophers have gone so far as to suppose that water is a constituent part of air; and that therefore it cannot be wholly abstracted without destroying the air altogether, or depriving it of its elastic state. This opinion has been adopted by Dr Priestley in particular; and that philosopher has founded on it the objections which he has urged against the composition of water. The experiments of Mr Henry upon carbona-

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l hydrogen gas have demonstrated, that air, even af-
it has been exposed to the action of the driest salts,
d those which have the strongest affinity for moisture,
ll retains a portion of water; but this portion is ex-
dingly small, and may, when the precautions of Saus-
e are taken, be neglected altogether without any sen-
le error. Mr Henry has pointed out a way of free-
some of the gases altogether from water by the ac-
n of electricity. When they are thus completely pu-
ed from water, they continue to retain their elastic
m as much as ever. We may conclude, then, that
always contains water, but that water is not an in-
dient so essential as to be necessary to the very exist-
e of air in an elastic form; though a certain portion
it seems essential to render air fit to answer the diffe-
t purposes for which it is intended; very dry air
ing exceedingly unpleasant effects upon the animal
nomy, as has been remarked by Saussure and other
losophers. We may conclude also, that the abso-
e quantity of water assigned by Saussure as contain-
in air, corresponding to the different degrees of his
grometer, does not deviate very far from the truth.

State in which water exists in air.

With respect to the state in which water exists in
, there are only three different suppositions possible,
h of which has been supported by very able philo-
hers. 1. Water may be dissolved in air in the same
nner as a salt is held in solution by water. 2. It
be mechanically mixed with air in the state of
am or vapour; or, 3. It may be chemically combi-
with air, after having been converted into vapour.

1. The first of these opinions was hinted at by Dr
oke in his *Micrographia*, and afterwards proposed
Dr Halley; but it was much more fully developed

by Mr Le Roy of Montpelier in 1751. Dr Hamilton of Dublin made known the same theory about the same time. The phenomena in general coincide remarkably well with this theory. The quantity of water which air is capable of holding in solution is increased by every augmentation of temperature, and diminished by cold, which is precisely analogous to almost all other solvents. These analogies, and several others which will easily suggest themselves to the reader, have induced by far the greater number of philosophers to adopt this opinion.

2. The second theory; namely, that water exists in air in the state of vapour, and merely mechanically mixed with it, has been embraced by De Luc in his last Treatise on Meteorology; at least his reasoning appear to me to lead to that conclusion. He has proved, I think in a conclusive manner, that water, at least whe it enters into the atmosphere is always in the state o vapour, and that it evaporates independently of air altogether: but surely this is not sufficient to establish i as a fact, that the vapour, after it has mixed with air remains merely in the state of a mechanical mixture. I it existed in that state, it would not surely be so difficult to separate it again as we find it to be.

3 The theory that water exists in the atmosphere in th state of vapour, chemically combined with air, was firs advanced by Saussure and afterwards combated by Mor veau and De Luc. But notwithstanding the argument of these very ingenious and acute philosophers, I can not help thinking it by far the most probable accoun of the matter that has hitherto appeared. My reason are as follows:

It is in the state of vapour.

In the *first* place, It cannot be doubted that the wa r which exists in air, is derived originally from the aters on the surface of the earth, which are exposed the action of the atmosphere. Accordingly we find at water, when exposed to the air, suffers a gra-ial diminution of bulk; and at last disappears alto-ether. This diminution of the water may be owing, ther to its gradual solution in air, or to its conversion to vapour. The last is the common opinion, as the enomenon is in common language ascribed to the *aporation* of the water. When water is placed in an chausted receiver, it diminishes in bulk even more ra-idly than in the open air. In this case, as no air is resent, we can only ascribe the diminution of bulk to ie conversion of the water into vapour. Accordingly e find upon examination, that the receiver is actually lled with water in the state of vapour. The presence f this vapour very soon, by its elasticity, puts an end o the evaporation of the water. Now, since water isappears equally whether air be present or not, nd exactly in the same manner, it is reasonable to scribe its disappearing in both cases to the same cause. ut in the exhausted receiver it is converted into va-our. Hence it is probable that it is converted into va-our also in the open air; and if so, it must exist in ir in the state of vapour.

In the *second* place, If the disappearing of water ex-osed to the open air were owing to solution and not to vaporation, it ought certainly to disappear more ra-idly when it is exposed to the action of a great quantity f air than when to a small quantity; for the quantity f any body dissolved is always proportional to the uantity of the solvent. But the very contrary is what ctually takes place with respect to the water contained in the air. Saussure has proved that water evaporates much faster at great heights than at the surface of the earth, even when the temperature and the moisture of the air in both places are the same. By comparing a set of experiments made upon the Col-du-Geant, at the height of 11,275 feet above the level of the sea, with a similar set made at Geneva 1324 feet above the level of the sea, he ascertained, that supposing the temperature and the dryness of the air in both places the same, the quantity of water evaporated at Geneva is to that evaporated on the Col-du-Geant in the same time and same circumstances as 37 to 84, or nearly as 3 : 7. Now the air on the Col-du-Geant is about $\frac{1}{3}$d rarer than at Geneva; so that a diminution of about $\frac{1}{3}$d in the density of the air more than doubles the rate of evaporation *. This is precisely what ought to be the case, provided the water which disappears mixes with the air in the state of vapour only; but the very contrary ought to hold, if the water disappeared in consequence of the solvent power of air.

In the *third* place, It has been demonstrated by Dr Black that vapour is water combined with a certain dose of caloric. Consequently when water is converted into vapour, a certain portion of caloric combines with it and disappears. If, therefore, there is the same waste of caloric whenever water passes from a liquid state and enters into the atmosphere as a component part, we have reason to conclude that it enters into the atmosphere only in the state of vapour But it is a well known fact, that cold is always generated during spontaneous evaporation; that is to say, that the water as it dis-

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* Saussure's *Voyages dans les Alpes*, iv. 263.

ppears carries off with it a quantity of caloric. It is ell known, that when a wet body is exposed to the r, its temperature is lowered by the evaporation which kes place upon its surface. Hence in warm countries ater is cooled by putting it into porous vessels, and posing it to the air. The water penetrates through e vessels, evaporates from their surface, and carries off much heat, as even in some cases to freeze the wa- r in the vessel. Saussure observed that the evapora- on from the surface of melting snow caused it to eeze again when the temperature of the surrounding r was 4.5° above the freezing point. Dr Black has ndered it probable that the quantity of caloric which isappears during spontaneous evaporation, is as great that which is necessary to convert water into steam. Ve have a right then to conclude, that water, when it aporates spontaneously, is always converted into va- our, and of course that it is only in that state that it nters into the atmosphere.

There may, indeed, be a small portion held in so- ution by air in the state of water; but this portion nust be too minute to be perceptible. We know, at ast, that water is capable of dissolving air, and that it ways holds a portion of it in solution. It has been certained, that the affinity by which air is retained by ater is so great, that several hours boiling are scarcely fficient to separate it completely. Now, if water be pable of dissolving air, why may not air be capable lso of dissolving water? And if so, it is reasonable to ppose that air always holds some water in solution in e state of water. But as water dissolves only a very nall portion of air, and as air is a much rarer fluid han water, it is reasonable to conclude that it will dissolve proportionably less. But if this supposition be allowed, the quantity of water held in solution in air, in the state of water, must be very minute.

Let us conclude, then, with Saussure and De Luc, that almost the whole of the water which exists in the atmosphere is in the state of vapour. But we know from the nature of vapour, that whenever it comes into contact with a colder body, it is condensed again into water. This is very different from what happens to the vapour of the atmosphere; it is not deposited (except at particular times) upon colder bodies, nor indeed does it exhibit any sensible proofs of its presence. It must therefore be prevented by some cause or other from being condensed, and from exhibiting the usual properties of vapour. This cause can only be its combination with air. Hence the reason that its properties are concealed, and that it can only be separated from air by bodies which have a strong affinity for water. Hence, too, the reason that moist air is specifically lighter than dry; a fact which would be inexplicable, on the supposition that the water dissolved in air existed not in the state of steam but of water.

Quantity of vapour in the atmosphere.

The water, then, which constitutes a component part of the atmosphere is chemically combined with air; but it exists in two different states. A small portion is held in solution in the state of water, but by far the greater proportion is in the state of an elastic fluid, whose specific gravity is to that of air as 10 to 12, and chemically combined with air in the same manner as one gas is combined with another. As the quantity of the water contained in the atmosphere varies considerably, it is impossible to ascertain its amount with any degree of accuracy. But let us suppose that the mean f Saussure's hygrometer is 70°, which corresponds retty well both with the observations of Saussure and umbolt*. In that case every cubic foot of air will ontain at an average 3.4 grains troy of water, or $\frac{1}{294}$th art of its weight. According to this estimation, the verage sum total of water contained in the atmosphere mounts to somewhat less than 39,703,877,424,193,939 s. avoirdupois. But the absolute quantity is probably onsiderably over-rated; for the humidity of the atmoshere diminishes very considerably as its height inreases, as we learn from the experiments both of Saussure and De Luc.

SECT. III.

OF CARBONIC ACID GAS.

THE existence of carbonic acid gas as a constituent part of the atmosphere, was observed by Dr Black immediately after he had ascertained the nature of that peculiar fluid. If we expose a pure alkali or alkaline earth to the atmosphere, it is gradually converted into a carbonat by the absorption of carbonic acid gas. This fact, which had been long known, rendered the inference that carbonic acid gas existed in the atmosphere unavoidable, as soon as the difference between a pure alkali and its carbonat had been ascertained to depend upon that acid. Not only alkalies and alkaline earths

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* *Jour. de. Phys.* xlviii. 195.

absorb carbonic acid when exposed to the air, but several of the metallic oxides also. Hence the reason that we so often find the native oxides in the state of carbonats. Thus *rust* is always saturated with carbonic acid.

Carbonic acid found at great heights.

Carbonic acid gas not only forms a constituent part of the atmosphere near the surface of the earth, but at the greatest heights which the industry of man has been able to penetrate. Saussure found it at the top of Mount Blanc, the highest point of the old continent; a point covered with eternal snow, and not exposed to the influence of vegetables or animals. Lime water diluted with its own weight of distilled water, formed a pellicle on its surface after an hour and three quarters exposure to the open air on that mountain; and slips of paper moistened with pure potass, acquired the property of effervescesing with acids after being exposed an hour and a half in the same place *. Now this was at a height no less than 15,668 feet above the level of the sea. Humbolt has more lately ascertained the existence of this gas in air, brought by Mr Garnerin from a height not less than 4280 feet above the surface of the earth, to which height he had risen in an air balloon †. This fact is a sufficient proof that the presence of carbonic acid in air does not depend upon the vicinity of the earth.

Chemically combined with air.

Now as carbonic acid gas is considerably heavier than air, it could not rise to great heights in the atmosphere unless it entered into combination with the air. We are warranted, therefore, to conclude that carbonic acid is not merely mechanically mixed, but that it is che-

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* Saussure's *Voyages*, iv. 199.

† *Jour. de Phys.* xlvii. 202.

nically combined with the other constituent parts of he atmosphere. It is to the affinity which exists beween carbonic acid and air that we are to ascribe the apidity with which it disperses itself through the atmosphere, notwithstanding its great specific gravity. Fontana mixed 20,000 cubic inches of carbonic acid gas with the air of a close room, and yet half an hour after he could not discover the traces of carbonic acid in that air. Water impregnated with carbonic acid, when exposed to the air, very soon loses the whole of he combined gas. And when a phial full of carbonic acid gas is left uncorked, the gas, as Bergman first ascertained, very soon disappears, and the phial is found filled with common air.

It is owing to this strong affinity between air and carbonic acid gas that it is so difficult to detect the presence of that gas in air by the common tests. Atmospheric air does not render lime water turbid, though agitated with it ever so long, or made to pass through it in ever so great a quantity. Neither has it any effect upon the most delicate vegetable blues. The great quantity of air with which it is combined, envelopes it in such a manner that these bodies are not powerful enough to abstract it. We must employ for that purpose substances which have a very strong affinity for that acid, as the alkalies, milk of lime, &c. These substances detect its presence by acquiring the property of effervescing with acids.

Proportion.

The difficulty of separating this gas from air has hitherto prevented the possibility of determining with accuracy the relative quantity of it in a given bulk of air; but from the experiments which have been made, we may conclude with some degree of confidence, that it is not very different from 0 01. From the experiments of Humbolt, it appears to vary from 0.005 to 0.01. This variation will by no means appear improbable, if we consider that immense quantities of carbonic acid gas must be constantly mixing with the atmosphere, as it is formed by the respiration of animals, by combustion, and several other processes which are going on continually. The quantity, indeed, which is daily formed by these processes is so great, that at first sight it appears astonishing that it does not increase rapidly. The consequence of such an increase would be fatal, as air containing 0.1 of carbonic acid extinguishes light, and is noxious to animals. But we shall find reason afterwards to conclude, that this gas is decomposed by vegetables as rapidly as it forms.

Quantity.

On the supposition that the carbonic acid gas contained in a given bulk of air amounts to 0 01, the absolute quantity of it in the atmosphere would amount to somewhat more than 119,111,632,272,581,818 lbs. avoirdupois: an enormous quantity, which undoubtedly serves some valuable purpose in the atmosphere, though our knowledge of the changes which go on in that great laboratory is at present too imperfect to enable us even to conjecture the uses to which it may be applied

SECT. IV.

OF THE OTHER BODIES FOUND IN THE ATMOSPHERE.

Composition of the atmosphere.

ROM the three preceding Sections we see that the atiosphere consists chiefly of three distinct elastic fluids nited together by chemical affinity; namely, air, vaour, and carbonic acid gas; differing in their proporons at different times and in different places; but that ie average proportion of each is

98.6	air
1.0	carbonic acid
0.4	water
100.0	

Other bodies contained in it.

ut besides these bodies which may be considered as ie constituent parts of the atmosphere, the existence f several other bodies has been suspected in it. I do ot mean in this place to include among those bodies ectric matter, or the substance of clouds and fogs, and iose other bodies which are considered as the active gents in the phenomena of meteorology, but to confine iyself merely to those foreign bodies which have been ccasionally found or suspected in air. Concerning iese bodies, however, very little satisfactory is known t present, as we are not in possession of instruments ifficiently delicate to ascertain their presence We can ideed detect several of them actually mixing with air, ut what becomes of them afterwards we are unable to ay.

Hydrogen gas.

1. Hydrogen gas is said to have been found in air situated near the crater of volcanoes, and it is very possible that it may exist always in a very small proportion in the atmosphere; but this cannot be ascertained till some method of detecting the presence of hydrogen combined with a great proportion of air be discovered.

2. Carbonated hydrogen gas is often emitted by marshes in considerable quantities during hot weather. But its presence has never been detected in air; so that in all probability it is again decomposed by some unknown process.

3. Oxygen gas is emitted abundantly by plants during the day. We shall afterwards find reason to conclude that this is in consequence of the property which plants have of absorbing and decomposing carbonic acid gas. Now as this carbonic acid is formed at the expence of the oxygen of the atmosphere, as this oxygen is again restored to the air by the decomposition of the acid, and as the nature of atmospheric air remains unaltered, it is clear that there must be an equilibrium between these two processes; that is to say, all the carbonic acid formed by combustion must be again decomposed, and all the oxygen abstracted must be again restored. The oxygen gas which is thus continually returning to the air, by combining with it, makes its component parts always to continue in the same ratio.

4. The smoke and other bodies which are continually carried into the air by evaporation, &c. are probably soon deposited again, and cannot therefore be considered with propriety as forming parts of the atmosphere. But there is another set of bodies which are occasionally combined with air, and which, on account of the powerful action which they produce on the human bo-

, have attracted a great deal of attention. These are own by the name of matters of *contagion*.

That there is a difference between the atmosphere different places, as far as respects its effects up- the human body, has been considered as an esta- ished point in all ages. Hence some places have been lebrated as healthy, and others avoided as pernicious, the human constitution. It is well known that in ts and mines the air is often in such a state as to suffo- te almost instantaneously those who attempt to breath Some places are haunted by peculiar diseases. is known that those who frequent the apartments of rsons ill of certain maladies, are extremely apt to tch the infection ; and in prisons and other places, here crowds of people are confined together, when dis- ses once commence, they are wont to make dreadful voc. In all these cases it has been supposed that a cer- in noxious matter is dissolved by the air, and that it the action of this matter which produces the mis- ief.

Contagious matter,

This noxious matter is in many cases readily distin- uished by the peculiarly disagreeable smell which it mmunicates to the air. No doubt this matter differs cording to the diseases which it communicates, and e substance from which it has originated. Morveau ely attempted to ascertain its nature; but he soon und the chemical tests hitherto discovered altogether sufficient for that purpose. He has put it beyond a ubt, however, that this contagious matter is of a com- und nature, and that it is destroyed altogether by cer- in agents, particularly by those gaseous bodies which adily part with their oxygen. He exposed infected r to the action of various bodies, and he judged of the result by the effect which these bodies had in destroying the fetid smell of the air. The following is the result of his experiments.

How destroyed.

1. Odorous bodies, such as benzoin, aromatic plants, &c have no effect whatever. 2. Neither have the solutions of myrrh, benzoin, &c. in alcohol, though agitated in infected air. 3. Pyrolignous acid is equally inert. 4. Gunpowder, when fired in infected air, displaces a portion of it; but what remains still retains its fetid odour. 5. Sulphuric acid has no effect; sulphurous acid weakens the odour, but does not destroy it. 6. Acetous acid diminishes the odour, but its action is slow and incomplete. 7. Acetic acid acts instantly, and destroys the fetid odour of infected air completely. 8. The fumes of nitric acid, first employed by Dr Carmichael Smith, are equally efficacious. 9. Muriatic acid gas, first pointed out as a proper agent by Morveau himself, is equally effectual. 10. But the most powerful agent is oxy-muriatic acid gas, first proposed by Mr Cruickshanks, and now employed with the greatest success in the British Navy and Military hospitals.

Thus there are four substances which have the property of destroying contagious matter, and of purifying the air: but acetic acid cannot easily be obtained in sufficient quantity, and in a state of sufficient concentration to be employed with advantage. Nitric acid is attended with inconvenience, because it is almost always contaminated with nitrous gas. Muriatic acid and oxy-muriatic acid are not attended with these inconveniences; the last deserves the preference, because it acts with greater energy and rapidity. All that is necessary is to mix together two parts of salt with one part of

Chap. II.

black oxide of manganese, to place the mixture in open vessel in the infected chamber, and to pour up- it two parts of sulphuric acid. The fumes of oxy- ıriatic acid are immediately exhaled, fill the chamber, l destroy the contagion.

CHAP II.

OF METEOROLOGY.

HOUGH the phenomena of the weather must have at times attracted much of the attention of mankind, ause their subsistence and their comfort in a great asure depended upon them, it was not till the 17th tury that any considerable progress was made in in- tigating the laws of meteorology. How desirous so- r the ancients might have been to acquire an accu- e knowledge of this science, their want of proper in- uments entirely precluded them from cultivating it. the discovery of the barometer and thermometer in 17th century, and the invention of accurate electro- ters and hygrometers in the 18th, this defect is now tty well supplied; and philosophers are enabled to ke meteorological observations with ease and accura- Accordingly a very great number of such obser- ions have been collected, which have been arranged l examined from time to time by ingenious men, and sequences deduced from them, on which several different theories of the weather have been built. But meteorology is a science so exceedingly difficult, that, notwithstanding the united exertions of some of the first philosophers of the age, the phenomena of the weather are still very far from being completely understood; nor can we expect to see the veil removed, till accurate tables of observations have been obtained from every part of the world, till the atmosphere has been more completely explored, and the chemical changes which take place in it ascertained.

The changes which take place in the atmosphere demonstrate, in the clearest manner, that new combinations and decompositions are continually going on in it. On these chemical alterations the greater number of meteorological phenomena depend: they may be considered as the result of the mutual action of the different component parts of the atmosphere; and would admit of an easy explanation, if we were thoroughly acquainted with all those substances, and with the chemical laws which govern their action. The most important meteorological phenomena are, 1. The changes which take place in the weight of the atmosphere; 2. The changes which take place in its temperature; 3. The fogs, clouds, and rain which so often precipitate from it; 4. The violent agitation into which it is often thrown; and, 5. The electric phenomena which sometimes accompany or occasion these precipitations and agitations. The consideration of these subjects shall occupy the five following Sections.

SECT. I.

OF CHANGES IN THE WEIGHT OF THE ATMOSPHERE.

Height of the barometer on the sea shore.

VE have seen in the last Chapter, that the barometer
licates to us the weight of a column of air, extending
the top of the atmosphere, and whose base is equal
that of the mercury. At the level of the sea, where
e column of air is longest, the mean height of the ba-
meter is 30 inches. This Sir George Shuckburgh
und to be the case in the Mediterranean and the Chan-
l, in the temperature of 55° and 60°; Mr Bouguer,
the coast of Peru, in the temperature of 84°; and
rd Mulgrave, in latitude 80°. The mean height of
e barometer is less the higher any place is situated
ove the level of the sea, because the column of air
hich supports the mercury is the shorter. The ba-
meter has accordingly been used for measuring
ights. But if a barometer be allowed to remain in
e place, the mercury does not remain stationary;
metimes it rises and at other times falls, varying to
e extent of several inches; of course the weight of
e air which balances the mercury must be subject to
e same changes. Hence we learn that the air in the
me place is sometimes light and at other times heavy;
fferences which must be owing to changes in its quan-
ty. The barometer then informs us, that the quan-
ty of air above any spot is liable to continual altera-
ons. Consequently either the air accumulates in par-
cular spots, while it partially abandons others; or

Variation.

part of the atmosphere must be alternately abstracted altogether, and restored again by some constant though apparently irregular process.

Between the tropics the variations of the barometer are exceedingly small; and it is remarkable, that in that part of the world it does not descend above half as much for every 200 feet of elevation as it does beyond the tropics ||. In the torrid zone, too, the barometer is elevated about two thirds of a line twice every day; and this elevation happens at the same time with the tides of the sea ¶.

Annual range.

As the latitude advances towards the poles, the range of the barometer gradually increases, till at last it amounts to two or three inches. This gradual increase will appear from the following Table:

TABLE *of the Range of the Barometer.*

Latitude.	Places.	Range of the Barometer.	
		Greatest.	Annual.
0°	Peru	0.20 *	—
22 23	Calcutta	0 77 †	—
40 55	Naples	1.00 *	—
51 8	Dover	2.47 §	1.80
53 13	Middlewick	3.00 §	1.94
53 23	Liverpool	2.89 §	1.96
59 56	Petersburgh	3.45 ‡	2.77

|| M. Cassan, *Jour. de Phys.* April 1790, p. 268.

¶ Ibid.

* Kirwan, *Irish Trans.* vol. iii. p. 47.

† *Asiatic Researches*, vol. ii. Appendix.

§ *Manchester Trans.* vol. iv.

‡ *Edinburgh Trans.* vol. ii. p. 229.

In North America, however, the range of the baro- eter is a great deal less than in the corresponding Eu- pean latitudes. In Virginia, for instance, it never ceeds 1.1 *.

The range of the barometer is greater at the level of e sea than on the mountains, and in the same degree latitude the extent of the range is in the inverse ratio the height of the place above the level of the sea.

Diurnal range.

From a table published by Mr Cotte in the *Journal Physique* †, it seems exceedingly probable that the rometer has always a tendency to rise from the morn- g to the evening; and that this tendency is greatest tween two o'clock in the afternoon and nine at night, which hour the greatest elevation takes place; that e elevation of nine o'clock differs from that of two y $\frac{4}{12}$ths, while that at two differs from the morning levation only by $\frac{1}{12}$th; and that in certain climates the reatest elevation takes place at two o'clock. The fol- wing is a part of the Table on which these observa- ions are founded, reduced to the English standard.

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[*] *Trans. Philadel.* vol. ii. p. 142.

[†] Aug. 1790, p. 110.

Places.	Years of observation	Mean height of Barometer.			
		Morning.	Noon.	Evening.	Year.
Arles	6	29.9347	29.9347	29.9413	29.9347
Arras	6	29.6683	29.6683	29.6832	29.6758
Bourdeaux	11	29.7212	29.8385	29.8385	29.8385
Cambray	13	29.8756	29.8682	29.8756	29.8756
Chinon	12	29.7719	29.7795	29.8001	29.7869
Dunkirk	8	29.9199	29.9347	29.9347	29.9273
Hagenau	10	29.5648	29.5648	29.5741	29.5648
Laon	7	29.3354	29.3206	29.3429	29.3354
Lisle	6	29.9165	29.9274	29.9347	29.9077
Mayenne	7	29.7172	29.7056	29.7127	29.71[illegible]7
Manheim	5	29.6167	29.6018	29.6167	29.6093
Montmorenci	22	29.6536	29.6536	29.6610	29.6536
Mulhausen	7	29.1873	29.1800	29.1873	29.1873
Obernheim	12	29.4834	29.4665	29.4764	29.4764
Paris	67	29.8902	29.8607	29.8756	29.8756
Poitiers	12	29.7276	29.7276	29.7276	29.7276
Rouen	11	29.8607	29.8535	29.8535	29.8535
Rome	3	29.8607	29.8460	29.8756	29.8607
St Maurice le Gerard	10	29.8016	29.8016	29.8090	29.8016
Troyes	10	29.6885	29.6979	29.6885	29.6885

The range of the barometer is greater in winter than in summer. Thus at York the mean range of the barometer, during October, November, December, January, February, March, of the year 1774, was 1.42; and for the six summer months 1.016*.

In serene and settled weather it is generally high; and low in calm weather, when the air is inclined to rain; it sinks on high winds, rises highest on easterly and northerly winds, and sinks when the wind blows

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* *Manchester Trans.* vol. iv. p. 543.

from the south *. At Calcutta †, it is always highest when the wind blows from the north-west and north, and lowest when it blows from the south-east.

The barometer falls suddenly before tempests, and undergoes great oscillations during their continuance. Mr Copland ‡ of Dumfries has remarked, that a high barometer is attended with a temperature above, and a low barometer with one below, the monthly mean.

Such are the phenomena respecting the variations of the barometer, as far as they can be reduced under general heads. Various attempts have been made to explain them, but hitherto without any great degree of success. The theory of Mr Kirwan appears to me by far the most plausible, though it is not sufficient to explain all the facts. The following observations may be considered as a kind of abstract of his theory, except in one or two instances.

Atmosphere highest at the equator.

It is evident that the density of the atmosphere is least at the equator and greatest at the poles; for at the equator the centrifugal force, the distance from the centre of the earth, and the heat, all of which tend to diminish the density of the air, are at their maximum, while at the pole they are at their minimum. The mean height of the barometer at the level of the sea, all over the globe, is 30 inches; the weight of the atmosphere, therefore, is the same all over the globe. The weight of the atmosphere depends on its density and height: where the density of the atmosphere is greatest, its height must be least; and, on the contrary, where its density is least, its height must be greatest. The height

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[*] Dr Halley.

[†] *Asiatic Researches*, vol. ii. Appendix.

[‡] *Manchester Trans.* vol. iv.

of the atmosphere, therefore, must be greatest at the equator, and least at the poles; and it must decrease gradually between the equator and the poles, so that its upper surface will resemble two inclined planes, meeting above the equator their highest part *.

During summer, when the sun is in our hemisphere, the mean heat between the equator and the pole does not differ so much as in winter. Indeed the heat of northern countries at that time equals the heat of the torrid zone: thus in Russia, during July and August, the thermometer rises to 85° †. Hence the rarity of the atmosphere at the pole, and consequently its height, will be increased. The upper surface of the atmosphere, therefore, in the northern hemisphere will be less inclined; while that of the southern hemisphere, from contrary causes, will be much more inclined. The very reverse will take place during our winter.

The density of the atmosphere depends in a great measure on the pressure of the superincumbent column; and therefore decreases, according to the height, as the pressure of the superincumbent column constantly decreases. But the density of the atmosphere in the torrid zone will not decrease so fast as in the temperate and frigid zones; because its column is longer, and because there is a greater proportion of air in the higher part of this column. This accounts for the observation of Mr Cassan, that the barometer only sinks half as much for every 200 feet of elevation in the torrid as in the temperate zones ‡. The density of the atmosphere at

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* Kirwan, *Irish Trans.* vol. ii. p. 43, &c.

† Dr Guthrie, *Edin. Trans.* vol ii. p. 229.

‡ Should it not be examined whether the number of parts which the

the equator, therefore, though at the surface of the earth it is less, must at a certain height equal, and at a still greater surpass, the density of the atmosphere in the temperate zones and at the poles.

Hence the air, as it ascends, rolls towards the coldest pole.

A current of air is constantly ascending at the equator, and part of it at least reaches and continues in the higher parts of the atmosphere. From the fluidity of air, it is evident that it cannot accumulate above the equator, but must roll down the inclined plane which the upper surface of the atmosphere assumes towards the poles. As the surface of the atmosphere of the northern hemisphere is more inclined during our winter than that of the southern hemisphere, a greater quantity of the equatorial current of air must flow over upon the northern than upon the southern atmosphere; so that the quantity of our atmosphere will be greater during winter than that of the southern hemisphere: but during summer the very reverse will take place. Hence the greatest mercurial heights take place during winter, and the range of the barometer is less in summer than in winter.

Air accumulates over cold places.

The density of the atmosphere is in a great measure regulated by the heat of the place: wherever the cold is greatest, there the density of the atmosphere will be greatest, and its column shortest. High countries, and ranges of lofty mountains, the tops of which are covered with snow the greatest part of the year, must be much colder than other places situated in the same degree of latitude, and consequently the column of air over them much shorter. The current of superior air

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mercury sinks for every 200 feet of elevation be not proportioned to the latitude of the place?

Book I.

will linger and accumulate over these places in its passage towards the poles, and thus occasion an irregularity in its motion, which will produce a similar irregularity in the barometer. Such accumulations will be formed over the north-western parts of Asia and over North America: hence the barometer usually stands higher, and varies less there than in Europe. Accumulations are also formed upon the Pyrenees, the Alps, the mountains of Africa, Turkey in Europe, Tartary, and Tibet. When these accumulations have gone on for some time, the density of the air becomes too great to be balanced by the surrounding atmosphere; it rushes down on the neighbouring countries, and produces cold winds which raise the barometer. Hence the rise of the barometer which generally attends north-east winds in Europe, as they proceed from accumulations in the north-west of Asia, or about the pole; hence, too, the north-west wind from the mountains of Tibet raises the barometer at Calcutta.

It is probable that considerable quantities of air are occasionally destroyed in the polar regions. When this happens, the atmosphere to the south rushes in to fill up the void. Hence south-west winds take place, and the barometer falls.

As the mean heat of our hemisphere differs in different years, the density of the atmosphere, and consequently the quantity of equatorial air which flows towards the poles, must also be variable. Hence the range of the barometer is different in different years. Does this range correspond to the mean annual heat; that is to say, is the range greatest when the heat is least, and least when the heat is greatest? In some years greater accumulations than usual take place in the mountainous parts in the south of Europe and Asia, owing, perhaps, to earlier falls of snow, or to the rays of the sun having been excluded by long continued fogs. When this takes place, the atmosphere in the polar regions will be proportionably lighter. Hence the prevalence of southerly winds during some winters more than others.

Why the barometer varies little between the tropics.

As the heat in the torrid zone never differs much, the density, and consequently the height of the atmosphere, will not vary much. Hence the range of the barometer within the tropics is comparatively small; and it increases gradually as we approach the poles, because the difference of the temperature, and consequently of the density, of the atmosphere increases with the latitude.

The diurnal elevation of the barometer in the torrid zone corresponding to the tides, observed by Mr Cassan and others, must be owing to the influence of the moon on the atmosphere. This influence, notwithstanding the ingenious attempts of D'Alembert and several other philosophers, seems altogether inadequate to account for the various phenomena of the winds. It is not so easy to account for the tendency which the barometer has to rise as the day advances, which seems to be established by Mr Cotte's table. Perhaps it may be accounted for by the additional quantity of vapour added to the atmosphere, which, by increasing the quantity of the atmosphere, may possibly be adequate to produce the effect.

The falls of the barometer which precede, and the oscillations which accompany, violent storms and hurricanes, show us that these phenomena are produced by very great rarefactions, or perhaps destruction of air, in particular parts of the atmosphere. The falls of the barometer, too, that accompany winds proceed from the same cause.

The falling of the barometer which generally precedes rain, remains still to be accounted for; but we know too little about the causes by which rain is produced to be able to account for it in a satisfactory manner.

SECT. II.

OF THE TEMPERATURE OF THE AIR.

THOUGH there is a considerable difference in every part of the world between the temperature of the atmosphere in summer and in winter; though in the same season the temperature of almost every day, and even every hour, differs from that which precedes and follows it; though the heat varies continually in the most irregular and seemingly capricious manner—still there is a certain mean temperature in every climate, which the atmosphere has always a tendency to observe, and which it neither exceeds nor comes short of beyond a certain number of degrees. What this temperature is, may be known by taking the mean of tables of observations kept for a number of years; and our knowledge of it must be the more accurate the greater the number of observations is.

Method of ascertaining the mean annual temperature.

The mean annual temperature is greatest at the equator (or at least a degree or two on the north side of it), and it diminishes gradually towards the poles, here it is least. This diminution takes place in arith- etical progression; or, to speak more properly, the nnual temperature of all the latitudes are arithmetical eans between the mean annual temperature of the e- uator and the pole. This was first discovered by Mr ayer; and by means of an equation which he found- on it, but rendered considerably plainer and simpler, Ir Kirwan has calculated the mean annual temperature f every degree of latitude between the equator and the ole. He proceeded on the following principle. Let e mean annual heat at the equator be m, and at the ole $m - n$; put Φ for any other latitude; the mean nnual temperature of that latitude will be $m - n \times$ sin. ^{2}. If therefore the temperature of any two latitudes e known, the value of m and n may be found. Now e temperature of north lat. 40° has been found by e best observations to be 62.1°, and that of lat. 50°, 2 9°. The square of the sine of 40° is nearly 0.419, nd the square of the sine of 50° is nearly 0.586. herefore

$$m - 0.41\,n = 62.1, \text{ and}$$
$$m - 0.58\,n = 52.9; \text{ therefore}$$
$$62.1 + 0.41\,n = 52.9 + 0.58\,n, \text{ as each}$$

f them, from the two first equations, is equal to m. rom this last equation the value of n is found to be 3 nearly; and m is nearly equal to 84. The mean emperature of the equator therefore is 84°, and that f the pole 31°. To find the mean temperature for eve- y other latitude, we have only to find 88 arithmetical neans between 84 and 31. In this manner Mr Kir- van calculated the following TABLE:

TABLE *of the Mean Annual Temperature of the Standard Situation in every Latitude.*

Lat.	Temper.	Lat.	Temper.	Lat.	Temper.
90	31.	61	43 5	32	69.1
89	31.04	60	44.3	31	69.9
88	31.10	59	45.09	30	70.7
87	31.14	58	45 8	29	71.5
86	31.2	57	46.7	28	72.3
85	31.4	56	47.5	27	72.8
84	31.5	55	48.4	26	73.8
83	31.7	54	49.2	25	74.5
82	32.	53	50.2	24	75.4
81	32.2	52	51.1	23	75.9
80	32.6	51	52.4	22	76.5
79	32.9	50	52.9	21	77.2
78	33.2	49	53 8	20	77.8
77	33.7	48	54.7	19	78.3
76	34.1	47	55.6	18	78.9
75	34.5	46	56.4	17	79.4
74	35.	45	57.5	16	79.9
73	35.5	44	58.4	15	80.4
72	36.	43	59.4	14	80.8
71	36.6	42	60.3	13	81.3
70	37.2	41	61.2	12	81.7
69	37.8	40	62.	11	82.
68	38.4	39	63.	10	82.3
67	39.1	38	63.9	9	82.7
66	39 7	37	64.8	8	82.9
65	40.4	36	65.7	7	83.2
64	41.2	35	66.6	6	83.4
63	41.9	34	67.4	5	83 6
62	42.7	33	68.3	0	84

This Table, however, only answers for the temperature of the atmosphere of the ocean. It was calculated for that part of the Atlantic Ocean which lies between the 80th degree of northern and the 45th of southern latitude, and extends westwards as far as the Gulf-stream, and to within a few leagues of the coast of America; and for all that part of the Pacific Ocean reaching from lat. 45° north to lat. 40° south, from the 20th to the 275th degree of longitude east of London. This part of the ocean Mr Kirwan calls *the standard;* the rest of the ocean is subject to anomalies which will be afterwards mentioned.

Mean monthly temperature.

Mr Kirwan has also calculated the mean monthly temperature of the standard ocean. The principles on which he went were these: The mean temperature of April seems to approach very nearly to the mean annual temperature; and as far as heat depends on the action of the solar rays, the mean heat of every month is as the mean altitude of the sun, or rather as the sine of the sun's altitude. The mean heat of April, therefore, and the sine of the sun's altitude being given, the mean heat of May is found in this manner: As the sine of the sun's mean altitude in April is to the mean heat of April, so is the sine of the sun's mean altitude in May to the mean heat of May. In the same manner the mean heats of June, July, and August, are found; but the rule would give the temperature of the succeeding months too low, because it does not take in the heat derived from the earth, which possesses a degree of heat nearly equal to the mean annual temperature. The real temperature of these months therefore must be looked upon as an arithmetical mean between the astronomical and terrestrial heats. Thus in latitude 51°, the astronomical heat of the month of September is 44.6°, and the mean annual heat is 52.4°; therefore the real heat of this month should be $\frac{44.6+52.4}{2}$

= 48.5. Mr Kirwan, however, after going through a tedious calculation, found the results to agree so ill with observations, that he drew up the following TABLE, partly from principles and partly by studying a variety of sea journals.

TABLE *of the Monthly Mean Temperature of the Standard from lat.* 80° *to lat.* 10°.

Lat.	80°	79°	78°	77°	76°	75°	74°	73°	72°	71°
Jan.	22.	22.5	23.	23.5	24.	24.5	25.	25.5	26.	26.5
Feb.	23.	23.	23.5	24.	24.5	25.	25.5	26.	26.5	27.
Mar.	27.	27.5	28.	28.5	29.	29 5	30.	30.5	31	31.5
Apr	32.6	32.9	33.2	33.7	34.1	34.5	35.	35.5	36.	36.6
May	36.5	36.5	37.	37.5	38.	38.5	39.	39.5	40.	40.5
June	51.	51.	51.5	52.	52.	52.	52.5	53.	53.5	54.
July	50.	50.	50.5	51.	51.	51.	51.5	52.	52.5	53.
Aug.	39.5	40.	41.	41.5	42.	42.5	43.	43.5	44.	44.5
Sept.	33.5	34.	34.5	35.	35.5	36.	36.5	37.	38.	38.5
Oct.	28.5	29.	29.5	30.	30.5	31.	31.5	32.	32.5	33.
Nov.	23.	23.5	24.	24.5	25.	25.5	26.	26.5	27.	27.5
Dec.	22.5	23.	23.5	24.	24.5	25.	25.5	26.	26 5	27.

Lat.	70°	69°	68°	67°	66°	65°	64°	63°	62°	61°
Jan.	27.	27.5	27.5	28.	28.	28.	29.	30.	31.	32.
Feb.	27.5	28.	28.	28.5	29.	30.	31.	32.	33	34.
Mar.	32.	32.5	33.	33.5	34.	35.	36.	37.	38.	39.
Apr.	37.2	37.8	38.4	39.1	39.7	40.4	41.2	41.9	42 7	43.5
May	41.	41.5	42.	42.5	43.	44.	45.	46.	47.	48.
June	54.	54.5	54.5	54.5	55.	55	55.5	55.5	56.	56.
July	53.5	53.5	53 5	54.	54.5	54.5	55.	55.	55.5	55.5
Aug.	45.	45.5	46.	47.	48.	48.5	49.	50.	51.	52.
Sept.	39	39.5	40.	41.	42.	43.	44.	45.	46.	47.
Oct.	33.5	34.	34.	35.	36.	37.	37.5	38.	39.	40.
Nov.	28.	28.5	29.	30	31.	32.	32.5	33.	34.	35.
Dec.	27.5	28.	28.	29.	30.	30.5	31.	31.	32.	33.

Lat.	60	59°	58°	57°	56°	55°	54°	53°	52°	51°
Jan.	33.	34.	35.	36.	37.	38.	39.	40.	41.	42.
Feb.	35.	36.	37.	38.	39.	40.	41.	42.	43.	44.
Mar.	40.	41.	42.	43.	44.	45.	46.	48.	49.	50.
Apr.	44.3	45.09	45.8	46.7	47.5	48.4	49.2	50.2	51.1	52.4
May	49.	50.	51.	52.	53.	54.	55.	56.	57.	58.
June	56.	56.5	57.	57.	57.5	58.	58.5	59.	59.	60.
July	56.	56.5	57.	57.5	58.	59.	60.	61.	62.	63.
Aug.	53.	54.	55.	56.	57.	58.	59.	60.	61.	62.
Sept.	48.	49.	50.	51.	52.	53.	54.	55.	56.	57.
Oct.	41.	42.	43.	44.	45.	46.	47.	48.	49.	50.
Nov.	36.	37.	38.	39.	40.	41.	42.	43.	44.5	46.
Dec.	34.	35.	36.	37.	38.	39.	40.	41.	42.	44.

Lat.	50°	49°	48°	47°	46°	45°	44°	43°	42°	41°
Jan.	42.5	43.5	43.	42.5	44.	44.5	45	45.5	46.	46.5
Feb.	44.5	44.5	45.	45.5	46.	46.5	47.	48.	49.	50.
Mar.	50.5	51.	52.5	53.	53.5	54.5	55.5	56.5	58.5	59.5
Apr.	52.9	53.8	54.7	55.6	56.4	57.5	58.4	59.4	60.3	61.2
May	58.5	59.	60.	61.	62.	63.	64.	65.	66.	67.
June	61.	62.	63.	64.	65.	66.	67.	68.	69.	70.
July	63.5	64.	65.	66.	67.	68.	69.	69.5	70.	70.
Aug.	63.5	64.	65.	66.	67.	68.	69.	69.5	70.	70.
Sept.	58.5	59.	60.	61.	62.	63.	64.	66.	68.	69.5
Oct.	50.5	51.	52.	53.	54.	55.	56.	57.	58.	59.
Nov.	46.5	47.	48.	49.	50.	51.	52.	53.	54.	55.
Dec.	44.5	45.	46.	47.	48.	49.	50.	51.	52.	53.

Lat.	40°	39°	38°	37°	36°	35°	34°	33°	32°	31°
Jan.	49.5	51.	52.	53.5	55.	56.5	59.5	63.	63.	63.
Feb.	53.	56.5	58.	60.	61.	62.	63.	64.5	66.	67.
Mar.	60.	60.5	61.	62.	63.	64.	65.	66.5	67.5	68.5
Apr.	62.1	63.	63.9	64.8	65.7	66.6	67.4	68.3	69.1	69.9
May	68.	69.	70.	70.5	71.	71.5	72.	72.5	73.	73.
June	70.5	71.	71.	71.	71.5	71.5	72.	72.5	73.	73.
July	71.	71.	72.	72.	72.5	72.5	72.5	72.5	73.	73.
Aug.	71.	71.	72.	72.	72.5	72.5	72.5	72.5	73.	73.
Sept.	70.5	71.	71.5	72.	72.5	72.5	72.5	72.5	73.	73.
Oct.	60.	61.	62.	63.	64.	65.	66.	67.5	68.5	69.5
Nov.	56.	57.	58.	59.	60.	61.	62.	63.	64.5	65.5
Dec.	54.	55.	56.	57.	58.	59.	60.	61.	62.5	63.5

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Lat.	30°	29°	28°	27°	26°	25°	24°	23°	22°	21°	20
Jan.	63.5	63.5	63.5	64.	64.5	65.5	67.	68.	69.	71.	72.
Feb.	68.5	68.5	69.5	69.5	70.5	71.	72.	72.	72.5	74.	75.
Mar.	69.5	71.	72.	72.5	73.	73.5	74.5	75.	75.5	76.	77.
Apr.	70.7	71.5	72.3	72.8	73.8	74.5	75.4	75.9	76.5	77.2	77.
May	73.5	74.5	75.5	76.	76.5	77.5	78.	78.5	79.5	80.	80.
June	73.5	74.5	75.5	76.	76.5	78.	78.5	79.	79.5	80.	80
July	73.5	74.5	75.5	76.	76.5	78.	78.5	79.	79.5	80.	80.
Aug.	73.5	74.5	75.5	76.	76.5	78.	78.5	79.	79.5	80.	80.
Sept.	73.5	74.	75.5	76.	76.5	77.5	78.	78.5	79.	79.5	80.
Oct.	70.5	71.	72.5	72.5	73.	73.5	74.5	75.	75.5	77.	78.
Nov.	66.5	68.	69.	69.5	71.5	72.	73.5	74.	74.5	75.	75.
Dec.	64.5	66.	67.	67.5	68.5	69.5	70.	71.	71.5	72.	72.

Lat.	19	18°	17°	16°	15°	14°	13°	12°	11°	10°
Jan.	72.5	73.	73.5	74.	74.5	75.	76.	76.5	77.	77.5
Feb.	76.	76.5	77.	77.5	78.	78.5	79.	79.5	79.8	80.
Mar.	77.5	78.	78.5	79.	79.5	80.	80.8	81.	81.5	81.8
Apr.	78.3	78.9	79.4	79.9	80.4	80.8	81.3	81.7	82	82.3
May	81.	81.5	82.	82.5	83.	83	83.5	84.	84.	84.3
June	81.5	82.	82.5	83.	83.5	83.8	84.	84.3	84.6	84.8
July	81.5	82.	82.5	83.	83.5	83.8	84.	84.3	84.6	84.8
Aug.	81.5	82.	82.5	83.	83.5	83.8	84	84.3	84.6	84.8
Sept.	81.	81.5	82.	82.5	83.	83.	83.5	84.	84.3	84.6
Oct.	79.	80.	81.	81.5	82.	82.5	83.	83.5	83.8	84.
Nov.	76	77.	78.	78.5	79	79.	80.	80.5	80.8	81.
Dec.	73.	74.	75.	75.5	76.	76.5	77	77.5	78.	78.5

From this Table it appears that January is the coldest month in every latitude, and that July is the warmest month in all latitudes above 48°. In lower latitudes August is generally warmest. The difference between the hotest and coldest months increases in proportion to the distance from the equator. Every habitable latitude enjoys a mean heat of 60° for at least two months; this heat seems necessary for the production of corn. Within ten degrees of the poles, the temperatures dif-

r very little, neither do they differ much within ten
egrees of the equator ; the temperature of different
ars differ very little near the equator, but they differ
ore and more as the latitudes approach the poles.

Temperature of different heights above the sea.

The temperature of the earth at the level of the sea is
e same with that of the standard ocean ; but this tem-
erature gradually diminishes as we ascend above that
vel till, at a certain height, we arrive at the region of
erpetual congelation. This region varies in height ac-
rding to the latitude of the place ; it is highest at the
quator, and descends gradually nearer the earth as we
proach the poles. It varies also according to the sea-
n, being highest in summer and lowest in winter.
I. Bouguer found the cold on the top of Pinchinca,
ne of the Andes, to extend from seven to nine degrees
elow the freezing point every morning immediately
efore sun-rise. He concluded, therefore, that the
ean height of the *term of congelation* (the place where
first freezes during some part of the day all the year
und) between the tropics was 15,577 feet above the
vel of the sea; but in lat. 28° he placed it in sum-
er at the heigh of 13,440 feet. Now, if we take the
ifference between the temperature of the equator and
e freezing point, it is evident that it will bear the same
roportion to the term of congelation at the equator
at the difference between the mean temperature of
y other degree of latitude and the freezing point bears
the term of congelation in that latitude. Thus the
ean heat of the equator being 84°, the difference be-
veen it and 32 is 52 ; the mean heat of lat. 28° is
2.3°, the difference between which and 32 is 40.3 :
hen 52 : 15577 : : 40.3 : 12072. In this manner Mr
irwan calculated the following Table :

Lat.	Mean height of the Term of Congelation. Feet.
0	15577
5	15457
10	15067
15	14498
20	13719
25	13030
30	11592
35	10664
40	9016
45	7658
50	6260
55	4912
60	3684
65	2516
70	1557
75	748
80	120

If the elevation of a country above the level of the sea proceeds at a greater rate than six feet *per* mile, we must, according to Mr Kirwan *, for every 200 feet of elevation diminish the annual temperature of the standard in that latitude as follows. If the elevation be at the rate of

6 feet *per* mile,	$\frac{1}{4}$ of a degree
7 feet	$\frac{1}{3}$
13 feet	$\frac{4}{10}$
15 or upwards	$\frac{1}{2}$

Temperature at a distance from the sea.

According to him † also, for every 50 miles distance from the standard ocean, the mean annual temperature in

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* *Temperature of Latitudes*, p. 43.

† Ibid. p. 45.

different latitudes is to be depressed or raised nearly at the following rate :

From lat. 70° to lat 35° depressed $\frac{1}{3}$ of a degree
35 . . . . $\frac{1}{8}$
30 0
25 raised . . . . . . $\frac{1}{5}$
20 . . . . $\frac{1}{2}$
10 . . . . 1°

Variation in temperature explained.

The cause of the heat of the atmosphere is evidently the sun's rays; this has been observed and acknowledged in all ages. The heat which they produce is less according as they fall more obliquely; hence the temperature constantly diminishes from the equator to the pole, because their obliquity constantly increases with the latitude. But if the heat depended on the solar rays alone, it would disappear in the polar regions during winter when the sun ceases to rise. This, however, is by no means the case; the mean temperature, even at the pole, is 31°; and we find within the arctic circle as hot weather as under the equator. The reason of this is, that the sun's rays heat the earth considerably during summer: this heat it retains and gives out slowly during winter, and thus moderates the violence of the cold; and summer returns before the earth has time to be cooled down beyond a certain degree. This is the reason that the coldest weather does not take place at the winter solstice, but some time after, when the temperature of the earth is lowest; and that the greatest heat takes place also some considerable time after the summer solstice, because then the temperature of the earth is highest. For pure air is not heated by the solar rays which pass through it, but acquires slowly the temperature of the earth with which it is in contact.

This is the reason why the temperature decreases according to the elevation above the level of the sea.

Since the atmosphere is heated by contact with the superficies of the earth, its temperature must depend upon the capacity of that superficies for receiving and transmitting heat. Now this capacity differs very much in land and water. Land, especialy when dry, receives heat with great readiness, but transmits it through its own substance very slowly. Dr Hailes found, that in 1724, when the air and surface of the earth were both at 88°, a thermometer placed only two inches below the surface stood at 85°; another 16 inches below the surface, at 70°; and another 24 inches deep, at 68°. The two last mentioned thermometers retained the same temperature till the end of the month, though the temperature of the air frequently varied, and then fell only to 63° or 61°. The earth, at about 80 or 90 feet below its surface, constantly retains the same temperature; and this is nearly equal to the mean annual heat of the country. Hence the mean annual temperature of any country may be found out pretty accurately by examining the heat of deep wells or springs. Water, on the contrary, receives heat slowly, on account of its transparency; but what it does receive, is very quickly carried through the whole mass.

Land is often heated and cooled to a much greater degree than sea is. Dr Raymond often found the earth in the neighbourhood of Marseilles heated to 170°, but he never found the sea above 77°: in winter the earth was often cooled down to 14°, but the sea never lower than 45°. The sea atmosphere, therefore, ought to preserve a much more uniform temperature than the land atmosphere; and we find this in fact to be the

ise. The cause of the greater equability of water than
nd is evident. In summer the surface of the sea is
onstantly cooled down by evaporation; and in winter,
henever the surface is cooled, it descends to the bot-
m from its increased gravity, while its place is sup-
lied by warmer water. This process goes on conti-
ually, and the winter is over before the atmosphere
as been able to cool down the water beyond a certain
egree.

These observations will enable us to explain the dif-
erence which takes place between the annual tempera-
ure of the atmosphere above the ocean and that of
laces at some considerable distance from it. As the
a is never heated so highly as the land, the mean sum-
ner temperature at sea may be considered all over the
orld as lower than on land. During winter, when the
ower of the sun's rays in a great measure ceases, the
ea gives out heat to the air much more readily than the
arth: the mean winter temperature therefore at sea is
igher than on land; and in cold countries the difference
s so great, that it more than counterbalances the diffe-
ence which takes place in summer; so that in high la-
itudes the mean annual temperature ought to be great-
r at sea than on land. Accordingly from lat. 70° to
5°, to find the temperature of a place, the standard
emperature for the same latitude ought, according to
Mr Kirwan, to be depressed $\frac{1}{3}$d of a degree for every
o miles distance; for the cold which takes place in
winter always increases in proportion to the distance
rom the standard. At a less distance than 50 miles,
he temperatures of land and sea are so blended toge-
her by sea and land winds, that there is little difference
n the annual mean. In lower latitudes than 30°, the

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rays of the sun, even in winter, retain considerable power; the surface of the earth is never cooled very low, consequently the difference between the annual temperatures of the sea and land becomes less. As we approach nearer to the equator, the power of the solar rays during winter increases so that the mean winter temperature of the land atmosphere approaches nearer and nearer to that of the sea, till at last at the equator it equals it. After we pass lat. 30°, therefore, the mean annual land temperature gradually exceeds that of the sea more and more, till at the equator it exceeds it a degree for every 50 miles distance.

Exceptions.

Such then, in general, is the method of finding the mean annual temperature over the globe. There are, however, several exceptions to these general rules, which come now to be mentioned.

1. North Pacific Ocean.

That part of the Pacific Ocean which lies between north lat. 52° and 66° is no broader at its northern extremity than 42 miles, and at its southern extremity than 1300 miles: it is reasonable to suppose, therefore, that its temperature will be considerably influenced by the surrounding land, which consists of ranges of mountains covered a great part of the year with snow; and there are besides a great many high, and consequently cold, islands scattered through it. For these reasons Mr Kirwan concludes, that its temperature is at least 4 or 5 degrees below the standard. But we are not yet furnished with a sufficient number of observations to determine this with accuracy.

2. Southern hemisphere.

It is the general opinion that the southern hemisphere, beyond the 40th degree of latitude, is considerably colder than the corresponding parts of the northrn hemisphere. The probable cause of which will be ssigned in the Fourth Section of this Chapter.

3. Small seas.

Small seas surrounded with land, at least in tempe- ate and cold climates, are generally warmer in summer and colder in winter than the standard ocean, because they are a good deal influenced by the temperature of the land. The Gulph of Bothnia, for instance, is for the most part frozen in winter; but in summer it is sometimes heated to 70°; a degree of heat never to be found in the opposite part of the Atlantic *. The German Sea is above three degrees colder in winter, and five degrees warmer in summer than the Atlantic †. The Mediterranean Sea is, for the greater part of its extent, warmer both in summer and winter than the Atlantic, which therefore flows into it. The Black Sea is colder than the Mediterranean, and flows into it ‡.

4. North America.

The eastern parts of North America are much colder than the opposite coast of Europe, and fall short of the *standard* by about 10° or 12°, as appears from American Meteorological Tables. The causes of this remarkable difference are many. The highest part of North America lies between the 40th and 50th degree of north latitude, and the 100th and 110th degree of longitude west from London; for there the greatest rivers originate. The very height, therefore, makes this spot colder than it otherwise would be. It is covered with immense forests, and abounds with large swamps and morasses, which render it incapable of receiving any great degree of heat; so that the rigour of winter is much less tempered by the heat of the earth than in the old continent. To the east lie a number of very

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* *Mem. Stock.* 1776. † Kirwan's *Temperature of Lat.* p. 53. ‡ Ibid.

large lakes; and farther north, Hudson's Bay; about 50 miles on the south of which there is a range of mountains which prevent its receiving any heat from that quarter. This bay is bounded on the east by the mountainous country of Labrador and by a number of islands. Hence the coldnes of the north-west winds and the lowness of the temperature. But as the cultivated parts of North America are now much warmer than formerly, there is reason to expect that the climate will become still milder when the country is better cleared of woods, though perhaps it will never equal the temperature of the old continent.

5. Islands.

Islands are warmer than continents in the same degree of latitude; and countries lying to the windward of extensive mountains or forests are warmer than those lying to the leeward. Stones or sand have a less capacity for heat than earth has, which is always somewhat moist; they heat or cool, therefore, more rapidly and to a greater degree. Hence the violent heat of Arabia and Africa, and the intense cold of Terra del Fuego. Living vegetables alter their temperature very slowly, but their evaporation is great; and if they be tall and close, as in forests, they exclude the sun's rays from the earth, and shelter the winter snow from the wind and the sun. Woody countries, therefore, are much colder than those which are cultivated.

SECT. III.

OF EVAPORATION AND RAIN.

Nature of vapour.

We found reason formerly to conclude, that the water of the atmosphere exists in the state of *vapour.* We are indebted to the experiments of Saussure and De Luc for much of our knowledge of the qualities of vapour. It is an elastic invisible fluid like common air, but lighter; being to common air, according to Saussure, as 10 to 14, or, according to Kirwan, as 10 to 12: it cannot pass beyond a certain maximum of density, otherwise the particles of water which compose it unite together, and form small, hollow, visible vesicles, called *vesicular vapour;* which is of the same specific gravity with atmospherical air. It is of this vapour that clouds and fogs are composed. This maximum increases with the temperature; and at the heat of boiling water is so great, that steam can resist the whole pressure of the air, and exist in the atmosphere in any quantity.

Quantity of moisture evaporated annually.

Evaporation, at least in our climate, is about four times greater during the summer than the winter half-year: other things being equal, it is so much the more abundant the greater the difference is between the temperature of the air and of the evaporating surface; so much the less, the nearer they approach to the same temperature; and least of all when they actually arrive at it. Whenever the atmosphere is more than 15

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degrees colder than the evaporating surface, little evaporation takes place at all. Evaporation is powerfully promoted by winds, especially cold winds blowing into warm countries, or warm winds blowing into cold countries*. Tracts of land covered with trees or vegetables emit more vapour than the same space covered with water. From the experiments of Mr Williams, the quantity appears to be one-third more†: but the method in which these experiments were made (the same objection lies against several of Dr Hailes's experiments, the original discoverer of the fact) prevented him from ascertaining exactly the quantity of vapour emitted by plants. He made the plants grow in a box well closed up from the air, measured the quantity of water with which he supplied them, and at the end of the experiment weighed the box and the plants themselves. By this means he knew pretty accurately the quantity of water which the plants had absorbed, and which had afterwards disappeared; and all this he concluded had been emitted by the plants in the state of vapour. But it is possible that plants have the power of decompounding water, of retaining the hydrogen, and throwing off the oxygen. A part of the water then might be changed into air; and the quantity of this ought to have been ascertained and subtracted. Still, however, the quantity of vapour emitted by vegetables is very great. Evaporation is promoted by heat, and is therefore much greater in the torrid zone than in our latitudes. There, too, the difference between the quantities in summer and winter is much less than in our climate, because the difference

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* *Temperat. of Lat.* p. 12.

† *Trans. Philad.* ii. 121.

tween the temperature of the two seasons is less.
nimals also are continually throwing off vapour by
sensible perspiration ; the quantity of which is ex-
edingly different, according to the climate, season, and
mperament, and cannot therefore be calculated exact-
; but it must be very great.

From an experiment made by Dr Watson in Eng-
nd, during summer, when the earth had been burnt
by a month's drought without rain, it appears that
600 gallons of water were evaporated from a single
re in 12 hours.—If we were to suppose that this re-
esented the mean daily evaporation all over the globe,
would be easy to calculate the quantity of water
nually evaporated from the whole of its surface.
nd if we consider the state of the earth when the ex-
eriment was made, the situation of England nearer the
ole than the equator, and the evaporation constantly
oing on from animals and vegetables, which is not ta-
en in, we will surely not think the mean assumed too
reat. 1600 gallons in 12 hours is 3200 in 24 hours.
et us call it only 3000, which is equal to 693,000 cu-
ic inches. An acre contains 272,640 square inches ;
that the daily evaporation from every square inch
ill be about 0.11 of a cubic inch. This in a year
ill amount to somewhat more than 40 cubic inches
r every square inch. From the experiments of Mr
Villiams[*], it appears, that in Bradford in New Eng-
nd the evaporation during 1772 amounted to 42.65
ches. But from the way that his experiments were
onducted, the amount was probably too great. These
xperiments, however, serve to show that our calcula-

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[*] *Trans. Philad.* ii. 135.

tion is not perhaps very remote from the truth. Now 40 inches from every square inch on the superficies of the globe make 107,942 cubic miles, equal to the water annually evaporated over the whole globe.

Were this prodigious mass of water all to subsist in the atmosphere at once, it would increase its mass by about a twelfth, and raise the barometer nearly three inches. But this never happens, no day passes without rain in some part of the earth ; so that part of the evaporated water is constantly precipitated again. Indeed it would be impossible for the whole of the evaporated water to subsist in the atmosphere at once, at least in the state of vapour.

The higher regions of the atmosphere contain less vapour than the strata near the surface of the earth. This was observed both by Saussure and De Luc, who mentions several striking proofs of it.

At some height above the tops of mountains the atmosphere is probably still drier ; for it was observed both by Saussure and De Luc, that on the tops of mountains the moisture of the air was rather less during the night than the day. And there can be little doubt that every stratum of air descends a little lower during the night than it was during the day, owing to the cooling and condensing of the stratum nearest the earth. Vapours, however, must ascend very high, for we see clouds forming far above the tops of the highest mountains.

Rain never begins to fall while the air is transparent : the invisible vapours first pass their maximum, and are changed into vesicular vapours ; clouds are formed, and these clouds gradually dissolve in rain. Clouds, however, are not formed in all parts of the hoon at once; the formation begins in one particular t, while the rest of the air remains clear as before: is cloud rapidly increases till it overspreads the whole rizon, and then the rain begins.

Formation of clouds

It is remarkable, that though the greatest quantity vapours exist in the lower strata of the atmosphere, uds never begin to form there, but always at some nsiderable height. It is remarkable, too, that the part the atmosphere at which they form has not arrived the point of extreme moisture, nor near that point n a moment before their formation. They are not med, then, because a greater quantity of vapour had into the atmosphere than could remain there with- passing its maximum. It is still more remarkable, t when clouds are formed, the temperature of the t in which they are formed is not always lowered, ugh this may sometimes be the case. On the con- ry, the heat of the clouds themselves is sometimes ater than that of the surrounding air[*]. Neither i is the formation of clouds owing to the capacity of for combining with moisture being lessened by cold: ar from that, we often see clouds, which had remain- n the atmosphere during the heat of the day, disap- r in the night, after the heat of the air was dimi- ied.

And rain cannot be accounted for.

The formation of clouds and rain, then, cannot be ac- nted for by a single principle with which we are ac- inted. It is neither owing to the saturation of the osphere, nor the diminution of heat, nor the mix- of airs of different temperatures, as Dr Hutton poses; for clouds are often formed without any

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[*] De Luc *sur la Meteorol.* ii. 100.

wind at all either above or below them ; and even i this mixture constantly took place, the precipitation, instead of accounting for rain, would be almost imperceptible.

It is a very remarkable fact, that evaporation often goes on for a month together in hot weather without any rain. This sometimes happens in this country; it happens every year in the torrid zone. Thus at Calcutta, during January 1785, it never rained at all[*]; the mean of the thermometer for the whole month wa 66½ degrees; there was no high wind, and indeed during great part of the month little wind at all.

The quantity of water evaporated during such a drought must be very great ; yet the moisture of th air, instead of being increased, is constantly diminishing, and at last disappears almost entirely. For the dew which is at first copious, diminishes every night ; an if Dr Watson's experiment formerly mentioned be attended to, it will not be objected that the quantity o evaporation is also very much diminished. Of the ver dry state to which the atmosphere is reduced durin long droughts, the violent thunder-storms with whic they often conclude is a proof, and a very decisive one Now what becomes of all this moisture ? It is not accumulated in the atmosphere above the country fro which it was evaporated, otherwise the whole atmosphere would in a much less period than a month b perfectly saturated with moisture. If it be carried u daily through the different strata of the atmosphere and wafted to other regions by superior currents of ai how is it possible to account for the different electric

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[*] *Asiatic Researches*, ii. Appendix.

ite of the clouds situated between different strata, hich often produces the most violent thunder storms? re not vapours conductors of the electric fluid; and uld they not have daily restored the equilibrium the whole atmosphere through which they passed? d they traversed the atmosphere in this manner, re would have been no negative and positive clouds, d consequently no thunder-storms. They could not ve remained in the lower strata of the atmosphere, d been daily carried off by winds to other countries; there are often no winds at all during several days perform this office; nor in that case would the dews minish, nor could their presence fail to be indicated by hygrometer.

It is impossible for us to account for this remarkable t upon any principle with which we are acquainted. e water can neither remain in the atmosphere, nor s through it in the state of vapour. It must there- e assume some other form; but what that form is, how it assumes it, we know not.

There are then two steps of the process between eva- ation and rain, of which at present we are complete- ignorant: 1. What becomes of the vapour after it ers into the atmosphere. 2. What makes it lay aside new form which it must have assumed, and return in to its state of vapour, and fall down in rain. And these two steps be discovered by experiments and ervations, it will be impossible for us to give a ra- nal or a useful theory of rain.

Dr Pratt of Exeter has endeavoured to prove, in a y ingenious treatise, that water is decomposed du- g its evaporation, and converted into oxygen and hy- gen gas: but the absence of any perceptible quantity of this last gas in the atmosphere, even when rain is actually forming, cannot be accounted for unless we suppose that the products of the decomposition are different. Girtanner's theory, that azot is composed of hydrogen and oxygen, would remove every difficulty; but unfortunately that theory is not only destitute of proof, but militates against the known properties of water, azot, and hydrogen. We must therefore be cautious in drawing any conclusion till future discoveries have removed the obscurity in which the phenomena of rain are at present involved.

Quantity of rain.

The mean annual quantity of rain is greatest at the equator, and decreases gradually as we approach the poles. Thus at

[*]Granada, Antilles,	12° N. lat.	it is 126 inches
[*]Cape François, St Domingo	19° 46′	120
[†]Calcutta	22 23	81
[*]Rome	41 54	39
[‡]England	33	32
[§]Petersburgh	59 16	16

On the contrary, the number of rainy days is smallest at the equator, and increases in proportion to the distance from it. From north latitude 12° to 43° the mean number of rainy days is 78; from 43° to 46° the mean number is 103; from 46° to 50° it is 134; from 51° to 60°, 161[¶].

The number of rainy days is often greater in winter

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[*] Cotte, *Jour. de Phys.* Oct. 1791, p. 264.

[†] *Asiatic Researches*, i. and ii. Appendix.

[‡] *Phil. Trans.*

[§] *Edin. Trans.* ii. 244.

[¶] P. Cotte, Ibid.

an in summer ; but the quantity of rain is greater in mmer than in winter *. At Petersburgh, the num- r of rainy or snowy days during winter is 84, and e quantity which falls is only about five inches ; du- ng summer the number of rainy days is nearly the me, but the quantity which falls is about 11 inches †.

More rain falls in mountainous countries than in ins. Among the Andes it is said to rain almost per- tually, while in Egypt it hardly ever rains at all. If rain-gauge be placed on the ground, and another at me height perpendicularly above it, more rain will collected into the lower than into the higher; a proof at the quantity of rain increases as it descends, ow- g perhaps to the drops attracting vapour during their ssage through the lower strata of the atmosphere ere the greatest quantity resides. This, however, is t always the case, as Mr Copland of Dumfries dis- vered in the course of his experiments ‡. He ob- rved also, that when the quantity of rain collected in lower gauge was greatest, the rain commonly con- ued for some time ; and that the greatest quantity s collected in the higher gauge only either at the end great rains, or during rains which did not last long. ese observations are important, and may, if follow- out, give us new knowledge of the causes of rain. ey seem to show, that during rain the atmosphere is mehow or other brought into a state which induces to part with its moisture ; and that the rain conti- es as long as this state continues. Were a sufficient mber of observations made on this subject in different

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* P. Cotte, *Jour. de Phy*. Oct. 1791, 264.

† *Edin. Trans.* ii. 244.

‡ *Manchest. Trans.* iv. 619.

places, and were the atmosphere carefully analysed during dry weather, during rain, and immediately after rain, we might soon perhaps discover the true theory of rain.

Rain falls in all seasons of the year, at all times of the day, and during the night as well as the day; tho', according to M. Toaldo, a greater quantity falls during the day than the night. The cause of rain, then, whatever it may be, must be something which operates at all times and seasons. Rain falls also during the continuance of every wind, but oftenest when the wind blows from the south. Falls of rain often happen likewise during perfect calms.

It appears from a paper published by M. Cotte in the *Journal de Physique* for October 1791, containing the mean quantity of rain falling at 147 places, situated between north lat. 11° and 60°, deduced from tables kept at these places, that the mean annual quantity of rain falling in all these places is 34.7 inches. Let us suppose then (which cannot be very far from the truth) that the mean annual quantity of rain for the whole globe is 34 inches. The superficies of the globe consists of 170,981,012 square miles, or 686,401,498,471,475,200 square inches. The quantity of rain therefore falling annually will amount to 23,337,650,812,030,156,800 cubic inches, or somewhat more than 91,751 cubic miles of water. This is 16,191 cubic miles of water less than the quantity of water evaporated. It seems probable, therefore, if the imperfection of our data warrant any conclusion, that some of the vapour is actually decomposed in the atmosphere, and converted into oxygen and hydrogen gas.

The dry land amounts to 52,745,253 square miles, e quantity of rain falling on it annually therefore will nount to 30,960 cubic miles. The quantity of water nning annually into the sea is 13,140 cubic miles; a antity of water equal to which must be supplied by aporation from the sea, otherwise the land would soon completely drained of its moisture.

Rain in Britain.

The quantity of rain falling annually in Great Britain may be seen from the following TABLE:

Years of bservation.	Places.	Rain in inches.
3	Dover *	37.52
5	Ware, Hertfordshire *	23.6
8	London †	17.5
8	Kimbolton ‡	23.9
45	Lyndon §	22.210
5	Chatsworth, Derbyshire * . . .	27.865
8	Manchester *	43.1
18	Liverpool *	34.41
7	Lancaster *	40.3
5	Kendal *	61.223
14	Dumfries *	36.127
10	Braxholm, 44 miles south-west of Berwick ‖	31.26
5	Langholm ‖	36.73
5	Dalkeith ‖	25.124
20	Glasgow ¶	31.
8	Hawkhill **	28.966
	Mean	32.532

Manchest. Trans. iv.

Ibid. vol. lxxix. part 1.

Edin. Trans. i. 208.

** *Edin. Trans.* i. 333.

† *Phil. Trans.* Tables of Observations.

§ Mr Barker, Ibid.

¶ *Statist. Account of Scotland*, v. 245.

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In this country it generally rains less in March than in November, in the proportion at a medium of 7 to 12. It generally rains less in April than October in the proportion of 1 to 2 nearly at a medium. It generally rains less in May than September, the chances that it does so are at least as 4 to 3; but when it rains plentifully in May (as 1.8 inches or more), it generally rains but little in September; and when it rains one inch or less in May, it rains plentifully in September*.

SECT. IV.

OF WIND.

No phenomenon in meteorology has more engaged the attention of men of observation than the *winds*, or those currents which so often disturb the tranquillity of the atmosphere. The subject is not only curious, but highly interesting; for upon their direction and force navigation in a great measure depends; the temperature of climates is greatly influenced by them; and they are absolutely necessary to preserve the salubrity of the atmosphere. To be acquainted with the laws by which they are regulated, and to be able to calculate beforehand the consequences of these laws, has been in every age the eager wish of philosophers. But whether it has been owing to an improper method of studying this subject, or to its lying beyond the reach of the human fa-

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* Kirwan, *Irish Trans.* v. 21.

ulties, philosophers have not made that progress in it vhich the sanguine imaginations of some individuals led hem to expect. Many discoveries indeed have been nade; and from the numbers and the genius of the hilosophers at present engaged in this study, others qually important may be expected. But, notwithstandng this, many of the phenomena remain unexplaind, and a rational and satisfactory theory seems still eyond our reach. I shall in this Section give as comlete a detail as possible of the natural history of the inds in the different parts of the world, and then conider how they may be explained.

1. Winds in the torrid zone.

As the winds are much more regular between the ropics than in the temperate zones, it will be proper in he first place to begin with them.

Trade-wind.

In those parts of the Atlantic and Pacific Oceans hich lie nearest the equator, there is a regular wind uring the whole year called the *trade-wind.* On the orth side of the equator it blows from the north-east, arying frequently a point or two towards the north or ast; and on the south side of it, from the south-east; hanging sometimes in the same manner towards the outh or east. The space included between the second nd fifth degree of north latitude is the internal limit of hese two winds. There the winds can neither be said o blow from the north nor the south; calms are freuent, and violent storms. This space varies a little in atitude as the sun approaches either of the tropics.— n the Atlantic Ocean the trade-winds extend farther orth on the American than on the African coast; and s we advance westward, they become gradually more asterly, and decrease in strength *. Their force di-

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* Dr Halley, *Phil. Trans.* Abr. vol. ii. p. 134.

minishes likewise as we approach their utmost boundaries. It has been remarked also, that as the sun approaches the tropic of Cancer, the south-east winds become gradually more southerly, and the north-east winds more easterly: exactly the contrary takes place when the sun is approaching the tropic of Capricorn*.

Monsoons.

The trade-wind blows constantly in the Indian Ocean from the 10th degree of south latitude to near the 30th: But to the northward of this the winds change every six months, and blow directly opposite to their former course. These regular winds are called *monsoons*, from the Malay word *moossin*, which signifies "a season †." When they shift their direction, variable winds and violent storms succeed, which last for a month and frequently longer; and during that time it is dangerous for vessels to continue at sea.

The monsoons in the Indian Ocean may be reduced to two; one on the north and another on the south side of the equator; which extend from Africa to the longitude of New Holland and the east coast of China, and which suffer partial changes in particular places from the situation and inflection of the neighbouring countries.

1. Between the 3d and 10th degrees of south latitude the south-east trade-wind continues from April to October; but during the rest of the year the wind blows from the north-west ‡. Between Sumatra and New Holland this monsoon blows from the south during our summer months, approaching gradually to the south-

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* Dr Halley; *Phil. Trans.* Abr. vol. ii. p. 134.

† Forest's *Voyage*, p. 95.

‡ Dr Halley, *Phil. Trans.* Abr. vol. ii. .136.

east as we advance towards the coast of New Holland; it changes about the end of September, and continues in the opposite direction till April [*]. Between Africa and Madagascar its direction is influenced by the coast; for it blows from the north-east from October to April, and during the rest of the year from the south-west [†].

2. Over all the Indian Ocean, to the northward of the 3d degree of south latitude, the north-east trade-wind blows from October to April, and a south-west wind from April to October [‡]. From Borneo, along the coast of Malacca and as far as China, this monsoon in summer blows nearly from the south, and in winter from the north by east [§]. Near the coast of Africa, between Mozambique and Cape Guardefan, the winds are irregular during the whole year, owing to the different monsoons which surround that particular place. Monsoons are likewise regular in the Red Sea; between April and October they blow from the north-west, and during the other months from the south-east, keeping constantly parallel to the coast of Arabia [‖].

Monsoons are not altogether confined to the Indian Ocean; on the coast of Brazil, between Cape St Augustine and the island of St Catherine, the wind blows between September and April from the east or north-east, and between April and September from the south-west [¶]. The bay of Panama is the only place on the west side of a great continent where the wind shifts

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[*] Dr Halley, *Phil. Trans.* Abr. vol. ii. p. 136.

[†] Bruce's *Travels*, vol. i. p. 459.

[‡] Dr Halley, *Phil. Trans.* Abr. vol. ii. p. 136.

[§] Dr Halley, ibid.

[‖] Bruce's *Travels*, vol. i. ch. 4.

[¶] Sir Walter Raleigh's *Voyage*, Forest's *Voyage*, p. 97.

regularly at different seasons: there it is easterly between September and March; but between March and September it blows chiefly from the south and south-west.

Such in general is the direction of the winds in the torrid zone all over the Atlantic, Pacific, and Indian Oceans; but they are subject to particular exceptions, which it is proper to enumerate.—On the coast of Africa, from Cape Bayador to Cape Verde, the winds are generally north-west; from hence to the island of St Thomas near the equator they blow almost perpendicular to the shore, bending gradually, as we advance southwards, first to the west and then to the south-west*. On the coast of New Spain likewise, from California to the Bay of Panama, the winds blow almost constantly from the west or south-west, except during May, June, and July, when land-winds prevail, called by the Spaniards *Popogayos*. On the coast of Chili and Peru†, from 20° or 30° south latitude, to the equator, and on the parallel coast of Africa, the wind blows during the whole year from the south, varying according to the direction of the land towards which it inclines, and extending much farther out to sea on the American than the African coast. The trade winds are also interrupted sometimes by westerly winds in the Bay of Campeachy and the Bay of Honduras

As to the countries between the tropics, we are too little acquainted with them to be able to give a satisfactory history of their winds.

Sea and land breezes.

In all maritime countries between the tropics of any extent, the wind blows during a certain number of hours

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* Dr Halley, *Phil. Trans.* Abr. vol. ii. p. 136.

† Sir Walter Raleigh's *Voyage*.—Dr Garden, *Phil. Trans.* Abr. vol. ii. p. 152.

every day *from* the sea, and during a certain number *towards* the sea from the land; these winds are called the *sea* and *land breezes*. The sea-breeze generally sets in about ten in the forenoon, and blows till six in the evening; at seven the land breeze begins, and continues till eight in the morning, when it dies away*. During summer the sea-breeze is very perceptible on all the coasts of the Mediterranean Sea†, and even sometimes as far north as Norway‡.

Winds in St Lewis,

In the island of St Lewis on the coast of Africa, in 16° north latitude, and 16° west longitude, the wind during the rainy season, which lasts from the middle of July to the middle of October, is generally between the south and east; during the rest of the year it is for the most part east or north-east in the morning; but as the sun rises, the wind approaches gradually to the north, till about noon it gets to the west of north, and is called a *sea breeze*. Sometimes it shifts to the east as the sun descends, and continues there during the whole night. In February, March, April, May, and June, it blows almost constantly between the north and west§. In the island of Balama, which lies likewise on the west coast of Africa, in the 11th degree of north latitude, the wind during nine months of the year blows from the south-west; but in November and December a very cold wind blows from the north-east ||.

Balama,

Bornou,

In the kingdom of Bornou, which lies between the 16th and 20th degree of north latitude, the warm season is introduced about the middle of April by sultry

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* Marsden's *Hist. of Sumatra*, p. 17.—Buffon's *Nat. Hist.* vol. i. p. 385.

† Volney's *Travels*.

‡ Pontoppidon's *Nat. Hist. of Norway*.

§ Dr Schotte, *Phil Trans.* vol. lxx. art. 25.

|| P. Beaver, Esq. See Map in Wadstrom's *Essay on Colonization*.

Fezzan, winds from the south-east, which bring along with them a deluge of rain [*]. In Fezzan, which is situated about the 25th degree of north latitude and the 35th degree of east longitude, the wind from May to August blows from the east, south-east, or south-west, and is intensely hot [†].

Abyssinia, In Abyssinia the winds generally blow from the west, north-west, north, and north-east. During the months of June, July, August, September, and October, the north and north-east winds blow almost constantly, especially in the morning and evening; and during the rest of the year they are much more frequent than any other winds [‡].

East and West Indies. At Calcutta, in the province of Bengal, the wind blows during January and February from the south-west and south; in March, April, and May, from the south; in June, July, August, and September, from the south and south-east; in October, November, and December, from the north-west [§]. At Madras the most frequent winds are the north and north-east. At Tivoli in St Domingo, and at Iles de Vaches, the wind blows oftenest from the south and south-east [‖].—From these facts it appears, that in most tropical countries with which we are acquainted, the wind generally blows *from* the nearest ocean, except during the coldest months, when it blows *towards* it.

2. In the temperate zones. In the temperate zones the direction of the winds is by no means so regular as between the tropics. Even

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[*] *African Association*, p. 200.

[†] Ibid.

[‡] Bruce's *Travels*, vol. iv. p. 651.

[§] *Asiatic Researches*, vols. i. and ii. Append.

[‖] P. Cotte, *Jour. de Phys.* 1791.

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n the same degree of latitude we find them often blowing in different directions at the same time ; while their hanges are frequently so sudden and so capricious, that o account for them has hitherto been found imposible. When winds are violent, and continue long, hey generally extend over a large tract of country ; nd this is more certainly the case when they blow rom the north or east than from any other points*. By the multiplication and comparison of Meteorological Tables, some regular connection between the hanges of the atmosphere in different places may in ime be observed, which will at last lead to a satisfacory theory of the winds. It is from such tables chiefly hat the following facts have been collected.

In America,

In Virginia, the prevailing winds are between the south-west, west, north, and north-west ; the most frequent is the south-west, which blows more constantly n June, July, and August, than at any other season. The north-west winds blow most constantly in November, December, January, and February†.—At Ipswich in New England the prevailing winds are also between the south-west, west, north, and north-east ; the most frequent is the north-west‡: But at Cambridge, n the same province, the most frequent wind is the south-east§. The predominant winds at New York are the north and west‖: And in Nova Scotia north-west winds blow for three-fourths of the year¶.—The same wind blows most frequently at Montreal in Ca-

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* Derham's *Physico-Theology*, ch. ii.

† Jefferson's *Virginia*, p. 123.—*Trans. Philad.* ii. art. 10.

‡ *Trans. Amer. Acad.* i. 336.

§ M. Cotte, *Jour. de Phys.* 1791.

‖ Ibid.

¶ *Present State of Nova Scotia and Canada*, p. 38.

nada; but at Quebec the wind generally follows the direction of the river St Lawrence, blowing either from the north-east or south-west [*].—At Hudson's Bay westerly winds blow for three-fourths of the year; the north-west wind occasions the greatest cold, but the north and north-east are the vehicles of snow [†].

It appears from these facts, that westerly winds are most frequent over the whole eastern coast of North America; that in the southern provinces south-west winds predominate; and that the north-west become gradually more frequent as we approach the frigid zone.

In Egypt,

In Egypt, during part of May, and during June, July, August, and September, the wind blows almost constantly from the north, varying sometimes in June to the west, and in July to the west and the east; during part of September, and in October and November, the winds are variable, but blow more regularly from the east than any other quarter; in December, January, and February, they blow from the north, north-west, and west; towards the end of February they change to the south, in which quarter they continue till near the end of March; during the last days of March and in April they blow from the south-east, south, and south-west, and at last from the east; and in this direction they continue during a part of May [‡].

In the Mediterranean

In the Mediterranean the wind blows nearly three-fourths of the year from the north; about the equinoxes there is always an easterly wind in that sea, which is generally more constant in spring than in an-

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[*] Cotte, *Jour. de Phys.* 1791.

[†] Pennant's *Suppl. to Arctic Zool.* p. 41.

[‡] Volney's *Travels*, i. 58.

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umn*. These observations do not apply to the gut f Gibraltar, where there are seldom any winds exept the east and the west.—At Bastia, in the island f Corsica, the prevailing wind is the south-west†.

Asia,

In Syria the north wind blows from the autumnal quinox to November; during December, January, nd February, the winds blow from the west and southest; in March they blow from the south, in May om the east, and in June from the north. From this onth to the autumnal equinox the wind changes graually as the sun approaches the equator; first to the st, then to the south, and lastly to the west‡.—At agdad the most frequent winds are the south-west and orth-west; at Pekin, the north and the south§; at amtschatka, on the north-east coast of Asia, the preailing winds blow from the west‖.

South of Europe,

In Italy the prevailing winds differ considerably according to the situation of the places where the obserations have been made: At Rome and Padua they are ortherly, at Milan easterly ¶.—All that we have been ble to learn concerning Spain and Portugal is, that on e west coast of these countries the west is by far the ost common wind, particularly in summer; and that Madrid the wind is north-east for the greatest part the summer, blowing almost constantly from the Pyenean mountains**.—At Berne in Switzerland the preailing winds are the north and west; at St Gottard,

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[*] Volney's *Trav.* i. 59. and 65.

[†] Cotte, *Jour. de Phys.* 1791.

[‡] Volney's *Trav.* i. 326.

[§] Cotte, Ibid.

[‖] Pennant's *Arctic Zool.* p. cxiii.

[¶] Cotte, Ibid.

[**] Bohun's *Hist. of Winds*, p. 116.

the north-east; at Lausanne, the north-west and south-west*.

France,

Father Cotte has given us the result of observations made at 86 different places of France*; from which it appears, that along the whole south coast of that kingdom the wind blows most frequently from the north, north-west, and north-east; on the west coast, from the west, south-west, and north-west; and on the north coast, from the south-west. That in the interior parts of France the south-west wind blows most frequently in 18 places; the west wind in 14; the north in 13; the south in 6; the north east in 4; the south-east in 2; the east and north-west each of them in one. —On the west coast of the Netherlands, as far north as Rotterdam, the prevailing winds are probably the south-west, at least this is the case at Dunkirk and Rotterdam*. It is probable also that along the rest of this coast, from the Hague to Hamburgh, the prevailing winds are the north-west, at least these winds are most frequent at the Hague and at Franeker*.—The prevailing wind at Delft is the south-east; and at Breda the north and the east*.

Germany,

In Germany the east wind is most frequent at Gottingen, Munich, Weissemburg, Dusseldorf, Sagannm, Erford, and at Buda in Hungary; the south-east at Prague and Wirtzburg; the north-east at Ratisbon; and the west at Manheim and Berlin*.

Britain,

From an average of ten years of the register kept by order of the Royal Society, it appears that at London the winds blow in the following order:

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* Cotte, *Jour. de Phys.* 1791.

inds.	Days.	Winds.	Days.
uth-west	112	South-east	32
orth-east	58	East	26
orth-west	50	South	18
est	53	North	16

t appears, from the same register, that the south-
est wind blows at an average more frequently than
y other wind during every month of the year, and
at it blows longest in July and August; that the
rth-east blows most constantly during January, March,
pril, May, and June, and most seldom during February,
ary, July, September, and December; and that the
rth-west wind blows oftener from November to
arch, and more seldom during September and Octo-
r than any other months. The south-west winds
also most frequent at Bristol, and next to them are
north-east*.

The following Table of the winds at Lancaster has
en drawn up from a register kept for seven years at
at place†.

inds.	Days.	Winds.	Days.
uth-west	92	South-east	35
orth-east	67	North	30
uth	51	North-west	26
est	41	East	17

The following Table is an abstract of nine years
servations made at Dumfries by Mr Copland‡.

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* *Phil. Trans.* lxvi. 2.

† *Manch. Trans.* iv. 234.

‡ Ibid.

Book I.

WINDS.	DAYS.	WINDS.	DAYS.
South	82½	North	36½
West	69	North-west	25½
East	68	South-east	18½
South-west	50½	North-east	14½

The following TABLE is an abstract of seven years observations made by Dr Meek at Cambuslang near Glasgow*:

WINDS.	DAYS.	WINDS.	DAYS.
South-west	174	North-east	104
North-west	140	South-east	47

It appears, from the register from which this table was extracted, that the north-east wind blows much more frequently in April, May, and June, and the south-west in July, August, and September, than at any other period. The south-west is by far the most frequent wind all over Scotland, especially on the west coast. At Saltcoats in Airshire, for instance, it blows three-fourths of the year; and along the whole coast of Murray, on the north-east side of Scotland, it blows for two-thirds of the year. East winds are common over all Great Britain during April and May; but their influence is felt most severely on the eastern coast.

The following TABLE exhibits a view of the number of days during which the westerly and easterly winds blow in a year at different parts of the island. Under the term *westerly* are included the north-west, west, south-west, and south; the term *easterly* is taken in the same latitude.

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* *Statistical Account of Scotland*, v. 245.

Chap. II.

Years of Observ.	Places.	Wind. Westerly.	Wind. Easterly.
10	London - - -	233	132
7	Lancaster - - -	216	149
51	Liverpool * - -	170	175
9	Dumfries - - -	227.5	137.5
10	Branxholm, 54 miles south-west of Berwick †	232	133
7	Cambuslang - -	214	151
8	Hawkhill, near Edinburgh ‡	229.5	135.5
	Mean	217.4	144.7

Ireland,

In Ireland the south-west and west are the grand ade-winds, blowing most in summer, autumn, and inter, and least in spring. The north-east blows most spring, and nearly double to what it does in autumn nd winter. The south-east and north-west are nearly ual, and are most frequent after the south-west and est §.

North of Europe.

At Copenhagen the prevailing winds are the east nd south-east; at Stockholm, the west and north ¶. Russia, from an average of a register of 16 years, e winds blow from November to April in the following order:

	W.	N.W.	E.	S.W.	S.	N.E.	N.	S.E.
ays	45	26	23	22	20	19	14	12

nd during the other six months,

	W.	N.W.	E.	S.W.	S.	N.E.	N.	S.E.
ays	27	27	19	24	22	15	32	18

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* *Manchester Trans.* iv.

† *Edin. Trans.* i. 203.

‡ Ibid.

§ Rutty's *Hist. of the Weather*, &c. *in Dublin.*

¶ Cotte, *Jour. de Phys.* 1791.

The west wind blows during the whole year 72 days; the north-west 53; the south-west and north 46 days each. During summer it is calm for 41 days, and during winter for 21 *. In Norway the most frequent winds are the south, the south-west, and south-east. The wind at Bergen is seldom directly west, but generally south-west or south-east; a north-west, and especially a north-east wind, are but little known there†.

From the whole of these facts, it appears that the most frequent winds on the south coasts of Europe are the north, the north-east, and north-west; and on the western coast, the south-west: that in the interior parts which lie most contiguous to the Atlantic Ocean, south-west winds are also most frequent; but that easterly winds prevail in Germany. Westerly winds are also most frequent on the north-east coast of Asia.

3. South temperate zone.

It is probable that the winds are more constant in the south temperate zone, which is in a great measure covered with water, than in the north temperate zone, where their direction must be frequently interrupted and altered by mountains and other causes.

M. de la Baille, who was sent thither by the French king to make astronomical observations, informs us, that at the Cape of Good Hope the main winds are the south-east and north-west; that other winds seldom last longer than a few hours; and that the east and north-east winds blow very seldom. The south-east wind blows in most months of the year, but chiefly from October to April; the north-west prevails during the other six months, bringing along with it rain, an

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* Guthrie on the Climate of Russia, *Edin. Trans.* ii.

† Pontoppidan's *Nat. Hist. of Norway*, part i.

empests, and hurricanes. Between the Cape of Good Iope and New Holland the winds are commonly weserly, and blow in the following order: north-west, outh-west, west, north*.

In the great South Sea, from latitude 30° to 40° outh, the south-east trade-wind blows most frequently, specially when the sun approaches the tropic of Caricorn; the wind next to it in frequency is the north-west, and next to that is the south-west. From south atitude 40° to 50° the prevailing wind is the north-west, and next the south-west. From 50° to 60°, the most frequent wind is also the north-west, and next to t is the west†.

Thus it appears that the trade-winds sometimes exend farther into the south temperate zone than their usual limits, particularly during summer; that beyond their influence the winds are commonly westerly, and that they blow in the following order: north-west, south-west, west.

Such is the present state of the history of the direction of the winds. In the torrid zone they blow constantly from the north-east on the north side of the equator, and from the south-east on the south side of it. In the north temperate zone they blow most frequently from the south-west; in the south temperate zone from the north-west, changing, however, frequently to all points of the compass; and in the north temperate zone blowing particularly during spring from the north-east.

Velocity of the winds.

As to the velocity of the wind, its variations are almost infinite; from the gentlest breeze to the hurri-

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* Meteorological Tables at the end of Philip's and White's *Voyages*.

† Wales's *Meteor. Tables*.

cane which tears up trees and blows down houses. It has been remarked, that our most violent winds take place when neither the heat nor the cold is greatest; that violent winds generally extend over a great tract of country; and that they are accompanied with sudden and great falls in the mercury of the barometer. The wind is sometimes very violent at a distance from the earth, while it is quite calm at its surface. On one occasion Lunardi went at the rate of 70 miles an hour in his balloon, though it was quite calm at Edinburgh when he ascended, and continued so during his whole voyage. Let us now consider the cause of these numerous currents in the atmosphere.

Explanation of the cause of the trade-winds.

It cannot be doubted that the surface of the earth under the torrid zone is much more heated by the rays of the sun than under the frozen or temperate zones, because the rays fall upon it much more perpendicularly. This heat is communicated to the air near the surface of the torrid zone, which being thereby rarefied, ascends; and its place is supplied by colder air, which rushes in from the north and south.

Now the diurnal motion of the earth is greatest at the equator, and diminishes gradually as we approach the poles, where it ceases altogether. Every spot of the earth's surface at the equator moves at the rate of 15 geographical miles in a minute; at the 40° of latitude, it moves at about 11½ miles in a minute; and at the 30°, at nearly 13 miles. The atmosphere, by moving continually round along with the earth, has acquired the same degree of motion; so that those parts of it which are above the equator move faster than those which are at a distance. Were a portion of the atmosphere to be transported in an instant from latitude 30°

o the equator, it would not immediately acquire the
elocity of the equator; the eminences of the earth
herefore would strike against it, and it would assume
he appearance of an east wind. This is the case in a
naller degree with the air that flows towards the equa-
or, to supply the place of the rarefied air, which is con-
nually ascending; and this, when combined with its
eal motion from the north and south, must cause it to
ssume the appearance of a north-easterly wind on this
de the equator, and of a south-easterly beyond it.

The motion westwards occasioned by this difference
n celerity alone would not be great; but it is farther
ncreased by another circumstance. Since the rarefac-
on of the air in the torrid zone is owing to the heat
erived from the contiguous earth, and since this heat is
wing to the perpendicular rays of the sun, those parts
nust be hottest where the sun is actually vertical, and
onsequently the air over them must be most rarefied;
he contiguous parts of the atmosphere will therefore
e drawn most forcibly to that particular spot. Now
ince the diurnal motion of the sun is from east to west,
his hottest spot will be continually shifting westwards,
nd this will occasion a current of the atmosphere in
hat direction. That this cause really operates, appears
rom a circumstance already mentioned: when the sun
pproaches either of the tropics, the trade-wind on the
ame side of the equator assumes a more easterly di-
ection, evidently from the cause here mentioned; while
he opposite trade-wind, being deprived of this addi-
onal impulse, blows in a direction more perpendicular
o the equator.

The westerly direction of the trade-winds is still far-
her increased by another cause. Since the attraction

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of the sun and moon produces so remarkable an effect upon the ocean, we cannot but suppose that an effect equally great at least is produced upon the atmosphere. Indeed as the atmosphere is nearer the moon than the sea is, the effect produced by attraction upon it ought to be greater. When we add to this the elasticity of the air, or that disposition which it has to dilate itself when freed from any of its pressure, we cannot but conclude that the tides in the atmosphere are considerable. Now since the apparent diurnal motion of the moon is from east to west, the tides must follow it in the same manner, and consequently produce a constant motion in the atmosphere from east to west.

All these different causes probably combine in the production of the trade-winds; and from their being sometimes united, and sometimes distinct or opposite, arise all those little irregularities which take place in the direction and force of the trade-winds.

Why their limit is in the northern hemisphere.

Since the great cause of these winds is the rarefaction of the atmosphere by the heat of the sun, its ascension, and the consequent rushing in of colder air from the north and south, the internal boundary of the trade-winds must be that parallel of the torrid zone which is hottest, because there the ascension of the rarefied air must take place. Now since the sun does not remain stationary, but is constantly shifting from one tropic to the other, we ought naturally to expect that this boundary would vary together with its exciting cause; that therefore when the sun is perpendicular to the tropic of Cancer, the north-east trade-winds would extend no farther south than north latitude 23.5°; that the south-east wind would extend as far north; and that when the sun was in the tropic of Capricorn, the very con-ary would take place. We have seen, however, that ough this boundary be subject to considerable changes om this very cause, it may in general be considered fixed between the second and fifth degrees of north titude.

Though the sun be perpendicular to each of the opics during part of the year, he is for one half of it a considerable distance; so that the heat which they quire while he is present is more than lost during his bsence. But the sun is perpendicular to the equator wice in a year, and never farther distant from it than 3½° : being therefore twice every year as much heated, nd never so much cooled as the tropics, its mean heat ust be greater, and the atmosphere in consequence enerally most rarefied at that place. Why then, it will e asked, is not the equator the boundary of the two rade-winds? To speak more accurately than we have itherto done, the internal limit of these winds must be hat parallel where the mean heat of the earth is greatest. This would be the equator, were it not for a reason which shall now be explained.

It has been shewn by astronomers, that the orbit of he earth is an ellipsis, and that the sun is placed in one of the foci. Were this orbit to be divided into two arts by a straight line perpendicular to the transverse xis, and passing through the centre of the sun, one of hese parts would be less than the other; and the earth, during its passage through this smaller part of its orbit, would constantly be nearer the sun than while it moved through the other portion. The celerity of the earth's motion in any part of its orbit is always proportioned to its distance from the sun; the nearer it is to the sun, it moves the faster; the farther distant, the slower. The earth passes over the smaller portion of its orbit during our winter; which must therefore be shorter than our summer, both on account of this part of the orbit being smaller than the other, and on account of the increased celerity of the earth's motion. The difference, according to Cassini, is 7 days, 23 hours, and 53 minutes. While it is winter in the northern it is summer in the southern hemisphere; wherefore the summer in the southern hemisphere must be just as much shorter than the winter as our winter is shorter than our summer. The difference therefore between the length of the summer in the two hemispheres is almost 16 days. The summer in the northern hemisphere consists of 190½ days, while in the southern it consists only of 174½. They are to one another nearly in the proportion of 14 to 12.8; and the heat of the two hemispheres may probably have nearly the same proportion to one another. The internal limit of the trade-winds ought to be that parallel where the mean heat of the globe is greatest: this would be the equator, if both hemispheres were equally hot; but since the northern hemisphere is the hottest, that parallel ought to be situated somewhere in it; and since the difference between the heat of two hemispheres is not great, the parallel ought not to be far distant from the equator*.

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* This parallel could be determined by calculation, provided the mean heat of both the segments into which it divides the globe were known. Let the radius of this globe be = 1, the circumference of a great circle = 6, and consequently the arc of a great circle = 3, and the solid contents of a hemisphere = 2. Since the internal limit of the trade-winds is not far distant from the equator, we may consider that portion of the sphere intercepted between it and the equator as a cylinder, the base of which is the equator, and its height the arc intercepted between the equator and the internal limit of the trade-winds. Let this arc be x, and consequently

Cause of the monsoons,

The trade-wind would blow regularly round the whole globe if the torrid zone were all covered with water. f the Indian Ocean were not bounded by land on the north, it would blow there in the same manner as it oes in the Atlantic and Pacific Oceans. The rays of ight pass through a transparent body without communicating any, or at least but a small degree of heat. If piece of wood be inclosed in a glass vessel, and the ocus of a burning glass directed upon it, the wood will be burnt to ashes, while the glass through which all the ays passed is not even heated. When an opaque body s exposed to the sun's rays, it is heated in proportion o its opacity. If the bulb of a thermometer be exposed o the sun, the quicksilver will not rise so high as it would do if this bulb were painted black. Land is much more opaque than water; it becomes therefore much warmer when both are equally exposed to the influence

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he cylinder itself $= 3x$, equal to the excess of the southern segment nto which this internal limit divides the globe above the northern. Let he heat of the northern segment be $= n$, and that of the southern $= s$. The southern segment is $= 2 + 3x$, the northern $= 2 - 3x$. Now let us suppose that the bulk of each segment is reciprocally as its heat, nd we shall have this formula, $2 + 3x : 2 - 3x :: n : s$. Wherefore $= \frac{2n - 2s}{3n + 3s}$. Now if we suppose $n = 14$, and $s = 12.8$, $\frac{2n - 2s}{3n + 3s}$ $= \frac{24}{804}$. To reduce this value of x to degrees we must multiply it by o, since a great circle was made $= 6$: it gives 1° 48′ 27″ as the internal limit of the trade-wind. This is too small by 2° 11′ 33″. But the value which we have found is only that of the sine of the arc intercepted between the equator and the internal limit; the arc itself would be omewhat greater; besides, the proportion between the heat of the two egments is an assumed quantity, and may probably be greater than their difference in bulk: and one reason for this may be the great proportion of land in the northern compared with the southern segment. See the *Journal de Physique*, *Mai* 1791.

of the sun. For this reason, when the sun approaches the tropic of Cancer, India, China, and the adjacent countries, become much hotter than the ocean which washes their southern coasts. The air over them becomes rarefied and ascends, while colder air rushes in from the Indian Ocean to supply its place. As this current of air moves from the equator northward, it must, for a reason already explained, assume the appearance of a south-west wind; and this tendency eastward is increased by the situation of the countries to which it flows. This is the cause of the south-west monsoon, which blows during summer in the northern parts of the Indian Ocean. Between Borneo and the coast of China its direction is almost due north, because the country to which the current is directed lies rather to the west of north; a circumstance which counteracts its greater velocity.

In winter, when the sun is on the south side of the equator, these countries become cool, and the north-east trade-wind resumes its course, which, had it not been for the interference of these countries, would have continued the whole year.

As the sun approaches the tropic of Capricorn, it becomes almost perpendicular to New Holland: that continent is heated in its turn, the air over it is rarefied, and colder air rushes in from the north and west to supply its place. This is the cause of the north-west monsoon, which blows from October to April from the third to the tenth degree of south latitude. Near Sumatra its direction is regulated by the coast: this is the case also between Africa and Madagascar.

The same cause which occasions the monsoons gives rise to the winds which blow on the west coasts of frica and America. The air above the land is hotter d rarer, and consequently lighter than the air above e sea; the sea air therefore flows in, and forces the ghter land atmosphere to ascend.

And of the sea and land breezes.

The same thing will account for the phenomena of e sea and land breezes. During the day, the cool of the sea, loaded with vapours, flows in upon the nd, and takes the place of the rarefied land air. As e sun declines, the rarefaction of the land air is diinished: thus an equilibrium is restored. As the sea not so much heated during the day as the land, ither is it so much cooled during the night; because is constantly exposing a new surface to the atmosiere. As the night approaches, therefore, the cooler d denser air of the hills (for where there are no hills ere are no sea and land breezes) falls down upon the ains, and pressing upon the now comparatively lighter of the sea, causes the land-breeze.

The rarefied air which ascends between the second d fifth degrees of north latitude has been shewn to the principal cause of the trade-winds. As this air cends, it must become gradually colder, and conseently heavier; it would therefore descend again if it ere not buoyed up by the constant ascent of new rafied air. It must therefore spread itself to the north d south, and gradually mix in its passage with the wer air; and the greater part of it probably does not ach far beyond the 30°, which is the external limit the trade-wind. Thus there is a constant circulaon of the atmosphere in the torrid zone; it ascends ar the equator, diffuses itself toward the north and uth, descends gradually as it approaches the 30°, and turning again towards the equator, performs the same rcuit.

Cause of south-west winds,

If the attraction of the moon and the diurnal moti of the sun have any effect upon the atmosphere, and that they have some effect can hardly be disputed, there must be a real motion of the air westwards within the limits of the trade-winds. The consequence of this westerly current is an easterly current on its north and south side, as has been demonstrated by D'Alembert. Hence the frequency of south-west winds over the Atlantic Ocean and the western parts of Europe.

It seems probable too that air is generated at the equator, either in consequence of the decomposition of water or of some other cause. Hence the reason that south-west winds are so frequent, particularly in summer, and that they extend over a greater tract of country than most other winds which blow in the temperate zones. What has been said of south-west winds, holds equally with regard to north-west winds in the south temperate zone.

And north-east winds.

After south-west winds have blown for some time, a great quantity of air will be accumulated at the pole, at least if they extend over all the northern hemisphere: and it appears from comparing the tables kept by some of our late navigators in the Northern Pacific Ocean with similar tables kept in this island, that this is sometimes the case so far as relates to the Atlantic and Pacific Oceans. When this accumulation becomes great, it must, from the nature of fluids, and from the elasticity of air, press with a considerable and increasing force on the advancing air; so that in time it becomes stronger than the south-west wind. This will occasion at first a calm, and afterwards a north wind; which will become gradually easterly as it advances southwards, from its not assuming immediately the velocity

the earth. The mass of the atmosphere will be in-
eased in all those places over which this north-east
ind blows: this is confirmed by the almost constant
se of the barometer during a north-east wind.

Whatever tends to increase the bulk of the atmo-
here near the pole, must tend also to increase the fre-
iency of north-east winds; and if there be any sea-
n when this increase takes place more particularly,
at season will be most liable to these winds. During
inter the northern parts of Europe are covered with
ow, which is melted in the beginning of summer,
hen the heat of the sun becomes more powerful.
reat quantities of vapour are during that time raised,
hich will augment both the bulk and weight of the
mosphere; especially if part of this vapour be con-
rted into air. Hence north-east winds are most pre-
lent during May and June[*].

South-west wind occasioned by the decomposition of the atmosphere at the pole.

If water be decomposed in the atmosphere and hy-
ogen gas evolved, that gas, from its small specific gra-
ty, must accumulate near the poles, and be mixed with
e common air of the atmosphere, or with oxygen gas,
any be set at liberty. Now may not the appearance
the aurora borealis be owing to the union of oxygen
d hydrogen by the intervention of the electric fluid?

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[*] The frequency of north-east winds during these months is the great-
defect in the climate of Scotland, and is felt indeed severely over all
at Britain. In the united states of America, these winds keep pace
h the clearing of the land. Some time ago, in Virginia, they did not
ch farther than Williamsburgh; now they reach to Richmond, which
ituated considerably farther west, and are even beginning to be felt
l farther within the country (Jefferson's *State of Virginia*, p. 128.)
ght it not be possible then to prevent the frequency of these winds
this country, by planting trees along the whole east coast?

That it is an electrical phenomenon at least, can hardly be doubted. Artificial electricity is much strengthened during an aurora, as Mr Volta and Mr Canton have observed; and the magnetic needle moves with the same irregularity during an aurora that has been observed in other electrical phenomena, as we learn from Bergman and De la Lande. Many philosophers have attempted to demonstrate, that auroræ boreales are beyond the earth's atmosphere; but the very different results of their calculations evidently prove that they were not possessed of sufficient data.

If this conjecture be true, part of the atmosphere near the poles must at times be converted into water. This would account for the long continuance of south-west winds at particular times: when they do so, a decomposition of the atmosphere is going on at the pole. It would render this conjecture more probable, if the barometer fell always when a south-west wind continues long.

If this hypothesis be true, a south-west wind ought always to blow after auroræ boreales; and we are informed by Mr Winn * that this is actually the case. This he found never to fail in 23 instances. He observed also, that when the aurora was bright, the gale came on within 24 hours, but did not last long; but if it was faint and dull, the gale was longer in beginning and less violent, but it continued longer. This looks like a confirmation of the above conjecture. Bright auroræ are probably nearer than those which are dull. Now, if the aurora borealis be attended with a decomposition of a quantity of air, that part of the atmosphere which is nearest

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* *Phil. Trans.* for 1772.

must first rush in to supply the defect, and the motion will gradually extend itself to more distant parts. Just s if a hole were bored in the end of a long vessel filled with water; the water nearest the hole would flow out mmediately, and it would be some time before the water at the other end of the vessel began to move. The nearer we are to the place of precipitation, the ooner will we feel the south-west wind. It ought therefore to begin sooner after a bright aurora, because t is nearer than a dull and faint one. Precipitations of the atmosphere at a distance from the pole cannot be so great as those which take place near it; because the cold will not be sufficient to condense so great a quantity of hydrogen: south-west winds, therefore, ought not to last so long after bright as after dull auroræ. Winds are more violent after bright auroræ, because they are nearer the place of precipitation; just as the water near the hole in the vessel runs swifter than that which is at a considerable distance.

If these conjectures have any foundation in nature, there are two sources of south-west winds; the first has its origin in the trade-winds, the second in precipitations of the atmosphere near the pole. When they originate from the first cause, they will blow in countries farther south for some time before they are felt in those which are farther north; but the contrary will take place when they are owing to the second cause. In this last case, too, the barometer will sink considerably; and it actually does so constantly after auroræ, as we are informed by Mr Madison *, who paid particular attention to this subject. By keeping accurate meteorological tables

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* *Philad. Trans.* ii. 142.

in different latitudes, it might easily be discovered whether these consequences be true, and consequently whether the above conjectures be well or ill grounded.

Two sources of north-east winds.

There are also two sources of north-east winds; the first is an accumulation of air at the pole, the second a precipitation of the atmosphere in the torrid zone. For the discovery of this last cause we are indebted to Dr Franklin. In 1740 he was prevented from observing an eclipse of the moon at Philadelphia by a north-east storm, which came on about seven o'clock in the evening. He was surprised to find afterwards that it had not come on at Boston till near eleven o'clock: and upon comparing all the accounts which he received from the several colonies of the beginning of this and other storms of the same kind, he found it to be always an hour later the farther north-east, for every 100 miles.

" From hence (says he) I formed an idea of the course of the storm, which I will explain by a familiar instance I suppose a long canal of water stopped at the end by a gate. The water is at rest till the gate is opened; then it begins to move out through the gate, and the water next the gate is first in motion, and moves on towards the gate; and so on successively, till the water at the head of the canal is in motion, which it is last of all. In this case all the water moves indeed towards the gate; but the successive times of beginning the motion are in the contrary way, viz. from the gate back to the head of the canal. Thus, to produce a north-east storm, I suppose some great rarefaction of the air in or near the gulf of Mexico; the air rising thence has its place supplied by the next more northern, cooler, and therefore denser and heavier air; a sucessive current is formed, to which our coast and inland ountains give a north-east direction*."

Currents of air from the poles naturally, as has been bserved, assume a north-east direction as they advance uthwards; because their diurnal motion becomes less han that of the earth. Various circumstances, however, may change this direction, and cause them to become north, or even north-west, winds. The southest winds themselves may often prove sufficient for is; and violent rains, or great heat, by lessening or arefying the atmosphere in any country, will produce he same effect in countries to the westwards when orth winds happen to be blowing.

In North America, the north-west winds become graually more frequent as we advance northwards. The ast coast of this continent, where the observations ere made from which this conclusion was drawn, is lone cultivated; the rest of the country is covered with ood. Now cultivated countries are well known to be armer than those which are uncultivated; the earth n the latter is shaded from the sun, and never heated y his rays. The air, therefore, in the interior parts f America, must be constantly colder than near the ast coast. This difference will hardly be perceptible in he southern parts, because there the influence of the un is very powerful; but it will become gradually reater as we advance northwards, because the influence f the sun diminishes, and the continent becomes roader. Hence north-west winds ought to become ore frequent upon the east coast as we advance northards; and they will probably cease to blow so often

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* Franklin's *Philosophical Letters*, p. 389.

as soon as the whole continent of North America becomes cultivated.

East and west winds.

Such appear to be the causes which produce the more general winds that prevail in the torrid and temperate zones. The east and west winds, when they are not partial and confined to a very small portion of the atmosphere, seem to be nothing else but currents of air brought from the north or south by the causes already mentioned, and prevented from proceeding farther by contrary currents. If these currents have come from the north, they will assume the appearance of east winds; because their diurnal motion will be less than that of the more southern latitudes over which they are forced to remain stationary. The southern currents will become west winds for a contrary reason. This will furnish us with a reason for the coldness of east winds compared with west winds. If this account be true, there ought very frequently to be a west wind in a latitude to the south of those places where an east wind blows. This might easily be determined by keeping accurate registers of the winds in different latitudes, and as nearly as possible under the same meridian; and upon the result of these observations the truth or falsehood of the above conjecture must finally rest.

Partial winds.

Besides these more general winds, there are others which extend only over a very small part of the earth. These originate from many different causes. The atmosphere is composed of three different substances, air, vapour, and carbonic acid; to which may be added water. Great quantities of each of these ingredients are constantly changing their aerial form, and combining with various substances; or they are separating from other bodies, assuming the form of air, and ixing with the atmosphere. Partial voids, therefore, nd partial accumulations, must be continually taking lace in different parts of the atmosphere, which will ccasion winds varying in direction, violence, and connuance, according to the suddenness and the quantity f air destroyed or produced. Besides these there are any other ingredients constantly mixing with the atosphere, and many partial causes of condensation and arefaction in particular places. To these, and other auses probably hitherto unknown, are to be ascribed ll those winds which blow in any place besides the eneral ones already explained; and which, as they epend on causes hitherto at least reckoned contingent, vill probably for ever prevent uniformity and regularity n the winds. All these causes, however, may, and robably will, be discovered; the circumstances in vhich they will take place, and the effects which they will produce, may be known; and whenever this is the ase, the winds of any place may in some measure be reduced to calculation.

SECT. V.

OF ATMOSPHERICAL ELECTRICITY.

AIR is one of those bodies which have received the name of *electric*, because they are capable of being positively or negatively charged with electric matter. It not only contains that portion of electricity which seems necessary to the constitution of all terrestrial bodies, but it is liable also to be charged negatively or positively when electricity is abstracted or introduced by means of conducting bodies. These different states must occasion a variety of phenomena, and in all probability contribute very considerably to the various combinations and decompositions which are continually going on in air. The electrical state of the atmosphere, then, is a point of considerable importance, and has with great propriety occupied the attention of philosophers ever since Dr Franklin demonstrated that thunder is occasioned by the agency of electricity.

Electricity of the atmosphere.

1. The most complete set of observations on the electricity of the atmosphere were made by Professor Beccaria of Turin. He found the air almost always positively electrical, especially in the day-time and in dry weather. When dark or wet weather clears up, the electricity is always negative. Low thick fogs rising into dry air carry up a great deal of electric matter.

2. In the morning, when the hygrometer indicates dryness equal to that of the preceding day, positive electricity obtains even before sunrise. As the sun gets up, this electricity increases more remarkably if the dryness increases. It diminishes in the evening.

3. The mid-day electricity of days equally dry is proportional to the heat.

4. Winds always lessen the electricity of a clear day, especially if damp.

5. For the most part, when there is a clear sky and little wind, a considerable electricity arises after sunset at dew falling.

6. Considerable light has been thrown upon the sources of atmospherical electricity by the experiments of Saussure and other philosophers. Air is not only electrified by friction like other electric bodies, but the

ate of its electricity is changed by various chemical
erations which often go on in the atmosphere. Eva-
ration seems in all cases to convey electric matter in-
the atmosphere; and Saussure has ascertained that
e quantity of electricity is much increased when wa-
r is decomposed, as when water is dropt on a red hot
on. On the other hand, when steam is condensed into
sicular vapour, or into water, the air becomes nega-
vely electric. Hence it would seem that electricity
ters as a component part into water; that it separates
hen water is decomposed or expanded into steam, and
reunited when the steam is condensed again into
ater.

Farther, Mr Canton has ascertained that dry air, when
ated, becomes negatively electric, and positive when
oled, even when it is not permitted to expand or con-
act: and the expansion and contraction of air also oc-
sions changes in its electric state.

Sources of it.

Thus there are four sources of atmospheric electrici-
known: 1. Friction; 2. Evaporation; 3. Heat and
ld; 4. Expansion and contraction: not to mention
e electricity evolved by the melting, freezing, solu-
on, &c. of various bodies in contact of air.

Consequences of its accumulation.

7. As air is an electric, the matter of electricity, when
cumulated in any particular strata, will not immedi-
ely make its way to the neighbouring strata, but will
duce in them changes similar to what is induced up-
n plates of glass or similar bodies piled upon each
ther. Therefore if a stratum of air be electrified po-
tively, the stratum immediately above it will be ne-
ative, the stratum above that positive, and so on.
uppose now that an imperfect conductor were to come

into contact with each of these strata, we know from the principles of electricity that the equilibrium would be restored, and that this would be attended with a loud noise, and with a flash of light. Clouds which consist of vesicular vapours mixed with particles of air are imperfect conductors; if a cloud therefore come into contact with two such strata, a thunder clap would follow. If a positive stratum be situated near the earth, the intervention of a cloud will, by serving as a stepping-stone, bring the stratum within the striking distance, and a thunder clap will be heard while the electrical fluid is discharging itself into the earth. If the stratum be negative, the contrary effects will take place. It does not appear, however, that thunder is often occasioned by a discharge of electric matter from the earth into the atmosphere. The accidents, most of them at least, which were formerly ascribed to this cause, are now much more satisfactorily accounted for by Lord Stanhope's *Theory of the Returning Stroke.* Neither does it appear that electricity is often discharged into the earth, as the effects of few thunder-storms are visible upon the earth; that it is so sometimes, however, is certain.

Occasions a kind of combustion in air.

But it is not the province of chemistry to examine in detail the phenomena of thunder; that task must be resigned to the electrical philosopher. There is one remark, however, which cannot be omitted; it is this, that, during every discharge of electricity, whether natural or artificial, through air, some change similar to combustion undoubtedly takes place.* The light and the peculiar smell with which all electrical discharges are accompanied demonstrate this; for no light is perceptible

hen electricity is discharged in a vacuum. What
ie change is which electricity produces in air, or how
produces it, are questions which, in the present state
f our knowledge, are altogether insoluble. But the
ery extraordinary Galvanic phenomena which at pre-
ent occupy the attention of philosophers, promise not
nly to throw light upon this important subject, but to
emonstrate a much closer connection between chemis-
y and electricity than has hitherto been suspected.

BOOK II.

OF

WATERS.

MANKIND must have observed, very early, that the waters, which exist in such abundance in almost every part of the earth, differ considerably from each other in their taste and transparency, and in their fitness for serving as vehicles for food, and for the various purposes of domestic economy. These differences are occasioned by the foreign bodies which the aqueous fluid holds in solution or suspension; for water is never found native in a state of complete purity In some cases the quantity of these foreign matters is so minute as to have but little influence on the taste or the other properties of water; but in other cases, the foreign bodies alter its properties altogether, and render it noxious, or medicinal, or unfit for the preparation of food. In the present Book I shall take a general view of the different springs and collections of water; and give an account of their properties and component parts, as far as they have been hitherto ascertained. Now waters may be

ry conveniently divided into three classes: 1. Waters
hich may be used for dressing food, and the other pur-
ses of domestic economy to which water is usually
plied. These, for want of a better name, may be
lled *common water*. 2. Sea water. 3. Those waters
hich have been called *mineral*, in consequence of the
table quantity of mineral substances which they con-
in.—These three classes of waters shall form the sub-
t of the three following Chapters.

Divisible into three three classes.

CHAP. I.

OF COMMON WATERS.

OOD water is as transparent as crystal, and entirely
lourless. It has no smell, and scarcely any taste;
d in general the lighter it is, so much the better. If
compare the different waters which are used for the
mmon purposes of life with each other, and judge of
em by the above standard, we shall find them to differ
nsiderably from each other, according to the circum-
nces of their situation. These waters may be redu-
d under four heads; namely, 1. Rain water; 2. Spring
d river water; 3. Well water; 4. Lake water.

1. Rain water, unless when near a town or when col-
ted at the commencement of the rain, possesses the
operties of good water in perfection, and is as free
om foreign ingredients as any native water whatever.

Rain water.

Snow water.

The substances which it holds in solution are *air*, *carbonic acid*, *carbonat of lime*, and, according to Bergman, it yields some traces of *nitric acid*, and a little *muriat of lime*[*]. The existence of air in water was first pointed out by Boyle. Scheele has shewn that it is usually either in the state of oxygen, or at least contains an excess of oxygen, and that water absorbs oxygen gas in preference to common air. The quantity of air in good water does not exceed $\frac{1}{28}$th of the bulk. One hundred cubic inches of water contain generally about one cubic inch of carbonic acid gas. It is to the presence of these two elastic fluids that water owes its taste, and many of the good effects which it produces on animals and vegetables. Hence the vapidness of newly boiled water from which these gases are expelled. Snow water, when newly melted, is also destitute of all gaseous bodies[†]. Hence the reason that fish cannot live in it, as Carradori has ascertained[‡]. Hassenfratz, indeed, has endeavoured to prove, that snow water holds oxygen gas in solution; but in all probability the water which he examined had absorbed air from the atmosphere.

How purified.

The quantity of muriat of lime contained in rain water must be exceedingly minute; as Morveau has ascertained that rain water may be rendered sufficiently pure for chemical purposes by dropping into it a little barytic water, and then exposing it for some time to the atmosphere, and allowing the precipitate formed to deposite. According to that very accurate philosopher, the rain water which drops from the roofs of houses, after it has rained for some time, contains only a little

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[*] Bergman, i. 87.

[†] Ibid.

[‡] *Jour. de Phys.* xlviii. 226.

lphat of lime, which it has dissolved as it trickled ver the slates *.

Spring water.

2. The water of springs is nothing else than rain wa-r, which, gradually filtering through the earth, col-ects at the bottom of declivities, and makes its way to e surface. It is therefore equally pure with rain ater, provided it does not meet with some soluble ody or other in its passage through the soil. But as his is almost always the case, we generally find, even n the purest spring water, a little carbonat of lime nd common salt, besides the usual proportion of air nd carbonic acid gas. Sometimes also it contains mu-iat of lime or a little carbonat of soda †. Bergman ound the springs about Upsal, which are reckoned ex-eedingly pure, to contain the following foreign bo-ies:

1. Oxygen gas,
2. Carbonic acid,
3. Carbonat of lime,
4. Silica,
5. Common salt,
6. Sulphat of potass,
7. Carbonat of soda.
8. Muriat of lime.

The whole of these ingredients amounted at an ave-age to 0.00004 parts; and the proportion of each of he solid bodies was as follows:

Carbonat of lime	5.0	Muriat of lime	0.5
Common salt . . .	3.0	Sulphat of potass	0.25
Silica	0.5	Carbonat of soda	0.25

River water.

River waters may be considered as merely a collec-ion of spring and rain water, and therefore are usually possessed of a degree of purity at least equal to these. Indeed, when their motion is rapid and their bed sili-ceous sand, they are generally purer than spring wa-

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* *Ann. de Chim.* xxiv. 321.

† Bergman, i. 88.

ter; depositing during their motion every thing which was merely mechanically suspended, and retaining nothing more than the usual proportion of air and carbonic acid gas, and a very minute quantity of carbonated lime and common salt. When their bed is clayey, they are usually opal-coloured, in consequence of the particles of clay which they hold in suspension.

Well water.

3. By well water is meant the water which is obtained by digging deep pits, which is not in sufficient quantity to overflow the mouth of the well; but which may be obtained in abundance by pumping. It is essentially the same with spring water, being derived from the very same source; but it is more liable to be impregnated with foreign bodies from the soil, in consequence of its stagnation or slow filtration. Hence the reason that well water is often of that kind which is distinguished by the name of *hard water*, because it does not dissolve soap, and cannot be used for dressing several kinds of food. These properties are owing to the great proportion of earthy salts which it holds in solution. The most common of these salts is sulphat of lime. These earthy salts have the property of decomposing common soap: their acid unites with the alkali of the soap, while the earthy basis forms with the oil a soap not soluble in water, which envelopes the soap and gives it a greasy feel. These waters may be in general cured by dropping into them an alkaline carbonat. Mr Sennebier has shewn that well water usually contains a greater proportion of carbonic acid gas than spring or river water.

Hard waters.

Water of lakes.

4. The water of lakes is merely a collection of rain water, spring water, and river water, and of course contains precisely the same heterogeneous salts: But it

seldom so transparent as river water, being usually ntaminated with the remains of animal and vegetable dies which have undergone putrefaction in it. For lake water is often nearly stagnant, it does not opse the putrefaction of these bodies, but rather protes it ; whereas in river water, which is constantly motion, no putrefaction takes place. Hence the rea of the slimy appearance and the brownish colour ich often distinguishes lake water.

Marsh water contains a still greater proportion of imal and vegetable remains than lake water, because is altogether stagnant. Moss water is strongly imegnated with those vegetable bodies which constitute sses, and usually also contains iron.

CHAP. II.

OF SEA WATER.

HE Ocean is the great reservoir of water into ich the lakes and rivers empty themselves, and from ich is again drawn by evaporation that moisture ich, falling in showers of rain, fertilizes the earth, d supplies the waste of the springs and rivers. This nstant circulation would naturally dispose one to beve, *a priori*, that the waters of the ocean do not dif much from the waters of rivers and lakes : but noing would be more erroneous than such a conclusion ;

Book II.

for the sea water, as every one knows, differs materially from common water in its taste, specific gravity, and other properties. It contains a much greater proportion of saline matter, particularly of common salt, which is usually extracted from it. Indeed, if the sea were not impregnated with these saline bodies, the putrefaction of the immense mass of animal and vegetable matter which it contains would in a short time prove fatal to the whole inhabitants of the earth.

Quantity of sea water.

The absolute quantity of sea water cannot be ascertained, as its mean depth is unknown. Mr De la Place has demonstrated, that a depth of four leagues is necessary to reconcile the height to which the tides are known to rise in the main ocean with the Newtonian theory of the tides*. If we suppose this to be the mean depth, the quantity of water in the ocean must be immense. Even on the supposition that its mean depth is not greater than the fourth part of a mile, its solid contents (allowing its surface to be three-fourths of that of the superficies of the earth) would be 32,058,939¼ cubic miles.

Its properties.

Sea water has a very disagreeable bitter taste, at least when taken from the surface or near the shore; but when brought up from great depths, its taste is only saline†. Hence we learn that this bitterness is owing to the animal and vegetable bodies with which it is mixed near the surface. Its specific gravity varies from 1.0269 to 1.0285‡. It does no freeze till cooled down to zero of Fahrenheit's scale.

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* *Mem. Par.* 1776. p. 213.

† Bergman, i. 180.

‡ Bladh, Kirwan's *Geological Essays*, p. 355.

Saline contents.

It has been ascertained by the experiments of diffe-
nt chemists *, and especially by those of Bergman,
at sea water consists of water holding in solution mu-
ıt of soda, muriat of magnesia, and sulphat of lime;
sides the animal and vegetable bodies with which it
occasionally contaminated. The average quantity of
ine ingredients is $\frac{1}{28}$. Bergman found water taken
from the depth of 60 fathoms, near the Canaries, by
Sparrman, to contain $\frac{1}{24}$. Lord Mulgrave found
water at the back of Yarmouth sands to contain
out $\frac{1}{32}$ part. From the analysis of Bergman, it ap-
ars that the relative proportions of these saline con-
ıts are as follows:

30.911 common salt
6.222 muriat of magnesia
1.000 sulphat of lime

Composition

erefore, according to this analysis, 100 parts of sea
ter are composed of 96.00 water
3.25 common salt
0.64 muriat of soda
0.11 sulphat of lime

100.00

In different places.

As far as experiment has gone, the proportion of
ne contents does not differ much, whatever be the
tude in which the water of the ocean is examined.
d Mulgrave, in north latitude 80°, and 60 fathoms
ler ice, found the saline contents of sea water 0.0354;
atitude 74°, he found them 0.036; in latitude 60°,
34. Pages found sea water taken up in north lati-
e 45° and 39° to contain 0.04 of saline contents;

Ionnet, Lavoisier, Baumé, &c. have published analyses of sea water.

and Beaumé obtained by analysis, from water taken up by Pages in north latitude 34 and 14° exactly the same proportions of saline matter. In southern latitudes Pages found the following proportions of saline matters :

Latitude.	Saline Matter.
49° 50′	0.0416
46 0	0.045
40 30	0.04
25 54	0.04
20 0	0.039
1 16	0.035

From the experiments made by Bladh on the specific gravity of sea water in different latitudes, it appears that the water contains more salt at the tropics than towards the equator.

Specific gravity of water holding different proportions of salt in solution.

If we were acquainted with the proportion between the saline contents of sea water and its specific gravity, it would be easy in all cases to ascertain the quantity of saline matter merely by taking the specific gravity of the water we wish to examine. This would require a set of experiments on purpose ; dissolving in pure water different quantities of the salts contained in sea water in the proportions which they bear to each other, and ascertaining the specific gravity of every such solution. Dr Watson has given us a Table for ascertaining that point, as far as common salt is concerned ; and as the salt which he used was not perfectly pure, but contained a mixture of the different salts usually found in the sea, we may consider it as very nearly determining the proportion of saline contents in sea water as far as it goes. This TABLE therefore I shall here insert *.

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* Watson's *Chemical Essays*, v. 91.

Proport. of Salt.	Specific Gravity.	Proport. of Salt.	Specific Gravity.	Proport. of Salt.	Specific Gravity.
0	1.000	$\frac{1}{21}$	1.032		1.007
	1,206	$\frac{1}{24}$	1.029	$\frac{1}{108}$	1.006
	1.160	$\frac{1}{7}$	1.027	$\frac{1}{12}$	1.005
$\frac{1}{5}$	1.121	$\frac{1}{28}$	1.025	$\frac{1}{14}$	1.004
$\frac{1}{6}$	1.107	$\frac{1}{30}$	1.024	$\frac{1}{16}$	1.003
$\frac{1}{7}$	1.096	$\frac{1}{32}$	1.023	192	1,0029
$\frac{1}{8}$	1.087	$\frac{1}{36}$	1.020		1.0023
$\frac{1}{9}$	1.074	$\frac{1}{39}$	1.019	320	1.0018
$\frac{1}{12}$	1.059	$\frac{1}{42}$	1.015	$\frac{1}{448}$	1.0017
$\frac{1}{14}$	1.050	$\frac{1}{48}$	1.014	$\frac{1}{512}$	1.0014
$\frac{1}{15}$	1.048	$\frac{1}{54}$	1.013	578	1.0008
$\frac{1}{16}$	1.045	$\frac{1}{56}$	1.012	$\frac{1}{1024}$	1.0006
$\frac{1}{18}$	1.040	$\frac{1}{72}$	1.009		

This Table was calculated at a temperature between 6° and 55°; but Mr Kirwan has reduced part of it o the temperature of 62°, in order to compare it with he specific gravities of sea water taken at that temperature, or at least reduced to it. The specific gravities, thus altered by Kirwan, are as follows:

Proportion of Salt.	Specific Gravity at 62°.
$\frac{1}{24}$	1.0283
$\frac{1}{25}$	1.0275
$\frac{1}{26}$	1.0270
$\frac{1}{27}$	1.0267
$\frac{1}{28}$	1.0250
$\frac{1}{30}$	1.0233
$\frac{1}{39}$	1.0185
$\frac{1}{44}$	1.0033
$\frac{1}{56}$	1.0105
$\frac{1}{108}$	1.004
$\frac{1}{162}$	1.0023

This Table will enable us to ascertain the saline contents of sea water in different parts of the Atlantic and Indian Oceans, from the following TABLE of the specific gravity of sea water in different parts of these oceans, constructed by Bladh, and reduced by Kirwan to the temperature of 62° *.

Specific gravity of sea water in different places.

LATITUDE.	LONGITUDE †.	Sp. Gr. at 62°.
North.	East.	
59° 39′	8° 48′	1.0272
57 18	18 48	1.0269
	West.	
57 1	1 22	1.0272
54 00	4 45	1.0271
44 32	2 04	1.0276
	East.	
44 07	1 00	1.0276
40 41	0 30	1.0276
34 40	1 18	1.0280
29 50	0 00	1.0281
	West.	
24 00	2 32	1.0284
18 28	3 24	1.0281
16 36	3 37	1.0277
14 56	3 46	1.0275
10 30	3 49	1.0272
5 50	3 28	1.0274
2 20	3 26	1.0271
1 25	3 30	1.0273
South.		
0 16	3 40	1.0277
5 10	6 00	1.0277
10 00	6 05	1.0285
14 40	7 00	1.0284
20 06	5 30	1.0285
25 45	2 22	1.0281
	East.	
30 25	7 12	1.0279
37 37	68 13	1.0276

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* Kirwan's *Geol. Essays*, p. 350.

† The Lon. is counted from Tenerif

From this Table, compared with the last, we learn, at the ocean contains most salt between south latide 10° and 20°; the saline contents amounting to raer more than $\frac{1}{24}$. The quantity of salt between north titude 18° and 34° is rather less than $\frac{1}{24}$: at the euator it is nearly $\frac{1}{25}$. The proportion of salt is least f all in north latitude 57°, where it amounts to little ore than $\frac{1}{27}$.

Of the Baltic.

From the experiments of Wilcke, we learn that the altic contains much less salt than the ocean; that the roportion of its salt is increased by a west wind, and ill more by a north west wind. The specific gravity f the Baltic water, ascertained by this philosopher uner these different circumstances, and reduced by Mr irwan to the temperature of 62°, is exhibited in the llowing TABLE:

Specific Gravity.	
1.0039	Wind at E.
1.0067	Ditto at W.
1.0118	Storm at W.
1.0098	Wind at N.W.

From this Table it appears that the proportion of lt in the Baltic, when an east wind prevails, is only $\frac{1}{08}$; and that this proportion is doubled by a wester storm: a proof not only that the saltness of the Balc is derived from the neighbouring ocean, but that orms have a much greater effect upon the waters of e ocean than has been supposed *. The Euxine and aspian Seas, if we believe Tournefort, are less salt an the ocean †; but it is probable that the Mediteranean is at least as salt as the Atlantic.

Kirwan's *Geological Essays*, p. 356.

† Tournefort's *Voyages*, ii. 410.

The Dead

The water of the *Dead Sea* differs exceedingly from sea water. Its specific gravity is 1.2403; and it is saturated with salt containing no less than 44.4 *per cent.* of saline matter. According to the analysis of Lavoisier, it is composed of

55.60	water
38.15	muriat of lime and of magnesia
6.25	common salt
100.00*	

The water of this lake, therefore, ought to be distinguished from sea-water; and might with propriety be included among *mineral* waters.

CHAP III.

OF MINERAL WATERS.

Mineral waters explained.

ALL waters which are distinguished from common water by a peculiar smell, taste, colour, &c. and which in consequence of these properties cannot be applied to the purposes of domestic economy, have been distinguished by the appellation of *mineral waters*. These occur more or less frequently in different parts of the earth, constituting wells, springs, or fountains; sometimes of the temperature of the soil through which they

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[*] *Mem. Par.* 1778, p. 69.

pass, sometimes warm, and in some cases even at the boiling temperature. Many of these mineral springs attracted the attention of mankind in the earliest ages, and were resorted to by those who laboured under diseases, and employed by them either externally or internally as a medicine. But it was not till towards the end of the seventeenth century that any attempt was made to detect the ingredients of which these waters were composed, or to discover the substances to which they owed their properties.

Attempts to analyse them.

Mr Boyle may be considered as the first person who pointed out the method of examining water. He first ascertained the existence of air in it, and pointed out a number of tests, by means of which conjectures might be made concerning the saline bodies which the water examined held in solution. In 1665, Dominic du Clos attempted to examine the different mineral waters in France. He employed almost all the re-agents recommended by Boyle, and likewise added several of his own. In 1680, Hierne published a set of experiments on the mineral waters of Sweden. Soon after various improvements were introduced by Regis, Didier, Burlet, and Homberg; and in 1726 Boulduc pointed out a method of precipitating several of the saline contents of water by means of alcohol. But it was not till after the discovery of carbonic acid by Dr Black, that any considerable progress was made in ascertaining the composition of mineral waters. That subtile acid which is so often contained in them, and which serves as a solvent to many of the earths and even metallic bodies, had thwarted all the attempts of former chemists to detect the composition of these liquids. Since the discovery of that acid, the analysis of mineral waters has advanced with great rapidity, in consequence, chiefly, of the admirable dissertation on the analysis of mineral waters published by Bergman in 1778. Since that period much has been done by the labours of Gioanetti, Black, Klaproth, Westrum, Fourcroy, Brezé, Kirwan, and many other eminent chemists. So that notwithstanding the difficulty of the subject, scarcely any branch of chemistry has made greater progress, or is farther advanced than the knowledge of mineral waters.

Substances found in them.

The substances hitherto found in mineral waters amount to about 38, and may be reduced under the four following heads: 1. Air and its component parts, oxygen and azotic gas. 2. Acids. 3. Alkalies and earths. 4. Salts.

1. Air.

I. 1. Air is contained in by far the greater number of mineral waters: its proportion does not exceed $\frac{1}{11}$th of the bulk of the water.

2. Oxygen gas was first detected in waters by Scheele. Its quantity is usually inconsiderable; and it is incompatible with the presence of sulphurated hydrogen gas or iron.

3. Azotic gas was first detected in Buxton water by Dr Pearson. Afterwards it was discovered in Harrowgate waters by Dr Garnet, and in those of Lemington Priors by Mr Lambe.

2. Acids.

II. The only acids hitherto found in waters, except in combination with a base, are the four following; carbonic, sulphurous, boracic, and sulphurated hydrogen gas.

1. Carbonic acid was first discovered in Pyrmont water by Dr Brownrigg. It is the most common ingredient in mineral waters, 100 cubic inches of the wa-

ter generally containing from 6 to 40 cubic inches of this acid gas. According to Westrum, 100 cubic inches of Pyrmont water contain 187 cubic inches of it, or almost double its own bulk.

2. Sulphurous acid has been observed in several of the hot mineral waters in Italy, which are in the neighbourhood of volcanoes.

3. The boracic acid has also been observed in some lakes in Italy.

4. Sulphurated hydrogen gas constitutes the most conspicuous ingredient in those waters which are distinguished by the name of hepatic or sulphureous.

3. Alkalies and earths.

III. The only alkali which has been observed in mineral waters, uncombined, is soda; and the only earthy bodies are silica and lime.

1. Dr Black detected soda in the hot mineral waters of Geyzer and Rykum in Iceland; but in most other cases the soda is combined with carbonic acid.

2. Silica was first observed in waters by Bergman. It was afterwards detected in those of Geyzer and Rykum by Dr Black, and in those of Carlsbad by Klaproth. Hassenfratz observed it in the waters of Pougues, and Brezé in those of Pu. It has been found also in many other mineral waters.

3. Lime is said to have been found uncombined in some mineral waters; but this has not been proved in a satisfactory manner.

4. Salts.

IV. The only salts hitherto found in mineral waters are the following *sulphats*, *nitrats*, *muriats*, *carbonats*, and *hydrosulphurets*:

1. Sulphat of soda
2. ammonia
3. lime
4. magnesia
5. alumina
6. iron
7. copper
8. Nitrat of potass
9. lime
10. magnesia
11. Muriat of potass
12. soda
13. ammonia
14. barytes
15. Muriat of lime
16. magnesia
17. alumina
18. manganese
19. Carbonat of potass
20. soda
21. ammonia
22. lime
23. magnesia
24. alumina
25. iron
26. Hydrosulph. of lime
27. potass
28. And likewise borax.

Of these genera the carbonats and muriats occur by far most commonly, and the nitrats most rarely.

1. Sulphat of soda is not uncommon, especially in those mineral waters which are distinguished by the epithet *saline*.

2. Sulphat of ammonia is found in mineral waters near volcanoes.

3. Sulphat of lime is exceedingly common in water. Its presence seems to have been first detected by Dr Lister in 1682.

4. Sulphat of magnesia is almost constantly an ingredient in those mineral waters which have purgative properties. It was detected in Epsom waters in 1610, and in 1696 Dr Grew published a treatise on it.

5. Alum is sometimes found in mineral waters, but it is exceedingly rare.

6. and 7. Sulphat of iron occurs sometimes in volcanic mineral waters, and has even been observed in

ther places. But sulphat of copper is only found in ıe waters which issue from copper mines.

8. Nitre has been found in some springs in Hungary; ut it is exceedingly uncommon.

9. Nitrat of lime was first detected in water by Dr ome of Edinburgh in 1756. It is said to occur in some prings in the sandy deserts of Arabia.

10. Nitrat of magnesia is said to have been found in ome springs.

11. Muriat of potass is uncommon; but it has lately een discovered in the mineral springs of Uhleaborg in weden by Julin.

12. Muriat of soda is so exceedingly common in mineal waters, that hardly a single spring has been analysed ithout detecting some of it.

13. Muriat of ammonia is uncommon; but it has een found in some mineral springs in Italy and in iberia.

14. Muriat of barytes is still more uncommon; but ts presence in mineral waters has been announced by Bergman.

15. and 16. Muriats of lime and magnesia are comnon ingredients.

17. Muriat of alumina has been observed in waters y Dr Withering; but it is very uncommon.

18. Muriat of manganese was mentioned by Bergnan as sometimes occurring in mineral waters. It has ately been detected by Lambe in the waters of Lemingon Priors; but in an extremely limited proportion.

19. The presence of carbonat of potass in mineral waters has been mentioned by several chemists: if it does occur, it must be in a very small proportion.

20. But carbonat of soda is, perhaps, the most com-

mon ingredients of these liquids, if we except common salt and carbonat of lime.

21. Carbonat of ammonia has been discovered in waters; but it is uncommon.

22. Carbonat of lime is found in almost all waters, and is usually held in solution by an excess of acid. It appears from the different experiments of chemists, as stated by Mr Kirwan, and especially from those of Berthollet, that water saturated with carbonic acid is capable of holding in solution 0.002 of carbonat of lime. Now water saturated with carbonic acid at the temperature of 50°, contains very nearly 0.002 of its weight of carbonic acid. Hence it follows that carbonic acid, when present in such quantity as to saturate water, is capable of holding its own weight of carbonat of lime in solution. Thus we see that 1000 parts by weight of water, when it contains two parts of carbonic acid, is capable of dissolving two parts of carbonat of lime. When the proportion of water is increased, it is capable of holding the carbonat of lime in solution, even when the proportion of carbonic acid united with it is diminished. Thus 24,000 parts of water are capable of holding two parts of carbonat of lime in solution, even when they contain only one part of carbonic acid. The greater the proportion of water the smaller a proportion of carbonic acid is necessary to keep the lime in solution; and when the water is increased to a certain proportion, no sensible excess of carbonic acid is necessary. It ought to be remarked also, that water, how small a quantity soever of carbonic acid it contains, is capable of holding carbonat of lime in solution, provided the weight of the carbonic acid present exceed that of

e lime *. These observations apply equally to the ther earthy carbonats held in solution by mineral aters.

23. Carbonat of magnesia is also very common in ineral waters, and is almost always accompanied by rbonat of lime.

24. Carbonat of alumina is said to have been found waters; but its presence has not been properly ascer-ined.

25. But carbonat of iron is by no means uncommon; deed it forms the most remarkable ingredient in those aters which are distinguished by the epithet of *chaly-eat*.

26. and 27. The hydrosulphurets of lime and of soda ave been frequently detected in those waters which re called sulphureous or hepatic.

28. Borax exists in some lakes in Persia and Thibet; ut the nature of these waters has not been ascer-ined †.

5. Vegetable and animal matters.

Besides these substances, certain vegetable and ani-al matters have been occasionally observed in mineral vaters. But in most cases these are rather to be con-idered in the light of accidental mixtures than of real omponent parts of the waters in which they occur.

From the above enumeration, we are enabled to form pretty accurate idea of the substances which occur in nineral waters; but this is by no means sufficient to nake us acquainted with these liquids. No mineral vater contains all of these substances. Seldom are here more than five or six of them present together, nd hardly ever do they exceed the number of eight or

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[*] Kirwan *on Mineral Waters*, p. 15.

[†] Ibid. p. 8. &c.

ten. The proportion, too, in which they enter into mineral waters is generally small, and in many cases extremely so. Now in order to understand the nature of mineral waters, it is necessary to know the substances which most usually associate together, and the proportion in which they commonly associate. In the greater part of mineral waters there is usually some substance present which, from its greater proportion or its greater activity, stamps, as it were, the character of the water, and gives it those properties by which it is most readily distinguished. This substance of course claims the greatest attenton, while the other bodies which enter in a smaller proportion may vary or even be absent altogether, without producing any sensible change in the nature of the water. This circumstance enables us to divide mineral waters into classes, distinguished by the peculiur substance which predominates in each.

Mineral waters divided into four classes.

Accordingly they have been divided into four classes; namely,

1. Acidulous,	3. Hepatic,
2. Chalybeate,	4. Saline.

Let us take a view of each of these classes.

1. Acidulous.

1. The acidulous waters contain a considerable proportion of carbonic acid. They are easily distinguished by their acid taste, and by their sparkling like champaign wine when poured into a glass. They contain almost constantly some common salt, and in general also a greater or smaller proportion of the earthy carbonats.

2. Chalybeate.

2. The chalybeate waters contain a portion of iron, and are easily distinguished by the property which they have of striking a black with the tincture of nutgalls. The iron is usually held in solution by carbonic acid.

t very often happens that this acid is in excess ; in which case the waters are not only chalybeate but acidulous. This is the case with the waters of Spa and Pyrmont. In some instances the iron is in the state of sulphat. The waters holding the sulphat of iron cannot well be applied to medicinal uses : they may be readily distinguished by the property which they have of continuing to strike a black with tincture of nutgalls even after being boiled and filtered ; whereas boiling decomposes the carbonat of iron, and causes its base to precipitate.

3. Hepatic.

3. The hepatic or sulphureous waters are those which contain sulphurated hydrogen gas. These waters are easily distinguished by the odour of sulphurated hydrogen gas which they exhale, and by the property which they have of blackening silver and lead. The nature of the waters belonging to this class long puzzled chemists. Though they often deposite sulphur spontaneously, yet no sulphur could be artificially separated from them. The secret was at last discovered by Bergman. These waters are of two kinds : in the first the sulphurated hydrogen is uncombined; in the second it is united to lime or an alkali. They are frequently also impregnated with carbonic acid, and usually contain some muriats or sulphats.

4. Saline.

4. Saline waters are those which contain only salts n solution, without iron or carbonic acid in excess. They may be distinguished into four different orders. The waters belonging to the first order contain salts whose base is lime, and generally either the carbonat or the sulphat. They are known by the name of hard waters, and have but a slight disagreeable taste. The waters belonging to the second order are those in which

common salt predominates. They are readily recognized by their salt taste, and like sea water usually contain some magnesian and calcareous salts. The waters of the third order contain sulphat of magnesia. They have a bitter taste and are purgative. Finally, the waters of the fourth order are alkaline, containing carbonat of soda. They are easily distinguished by the property which they have of tinging vegetable blues green.

Such is a short view of the different classes of mineral waters. A pretty accurate notion may be formed of the salts which most commonly associate, and of the proportions of each, from the following TABLE, which exhibits a synoptical view of the component parts of a considerable number of mineral waters as analysed by different chemists.

	Water.	Gases. Cubic Inches.				Carbonats of				Muriats of				Sulphats of					
		Oxygen.	Carbonic acid.	Sulph. hydr.	Azotic.	Soda.	Lime.	Mag.	Iron.	Soda.	Lime.	Mag.	Potass.	Soda	Lime.	Mag.	Silica.	Alumina.	Resin.
Seltzer[a] . . .	8949	.435	13.068	—	—	5.22	78.3	6.32	—	13.74	—	—	—	—	—	—	—	—	—
Spa[a]	8933	—	9.8	—	—	1.85	1.85	4.35	0.70	0.21	—	—	—	—	—	—	—	—	—
Pyrmont[a] . .	8950	—	19.6	—	—	—	4.3	9.8	0.70	1.7	—	—	—	—	8.38	5.44	—	—	—
Aix la Chap.[a]	8940	—	—	13.06	—	15.25	5.98	—	—	6.21	—	—	—	—	—	—	—	—	—
Medvi[a] . . .	8933	—	6.53	8.71	—	—	—	—	0.92	—	0.11	—	—	—	—	—	—	—	—
Carlsbad[b] . .	25320	—	50.	—	—	38.5	12.5	—	$0.1\frac{1}{4}$	32.5	—	—	-	66.75	—	—	2.25	—	—
Lem. Priors[c]	5816	—	.5	—	3.5	—	—	—	.75	430.	—	11.5	—	15.2	112.	—	—	—	—
Pougues[d] . .	9216	—	16.7	—	—	10.4	12.4	1.2	—	2.2	—	—	—	—	—	—	3.2	0.35	—
Enghien[e] . .	92160	—	18.5	70.0	—	—	21.4	1.35	—	2 4	—	8.0	—	—	33.3	15.8	—	—	—
Luf[f]	36864	—	5.	2.	—	—	10.22	—	—	36.74	9.25	—	—	—	14.03	—	0.23	—	—
Geyzer[g] . . .	10000	—	—	—	—	0.95*	—	—	—	2.46	—	—	—	1.46	—	—	5.4	0.48	—
Uhleaborg[h] .	42250	—	10.7	—	—	—	1.9	—	1.2	5.7	—	—	1	—	0.8	—	1.7	—	—
Teplisz[i] . . .	22540	—	—	—	—	13.25	16.5	—	32.5	61.3	28.5	—	—	—	—	—	15.1	—	—
Kilburn[k] . .	138240	—	84.	36.	—	—	2.4	1.25	$.3\frac{1}{8}$	6.0	.6	12.8	—	28.2	13.0	91.0	—	—	.6

[a] Bergman.
[b] Klaproth.
[c] Lambe, *Manch.* v. 174.
[d] Hassenfratz, *Ann. de Chim.* i. 81.
[e] Fourcroy, Ibid. vi. 172.
[f] Brezé, Ibid. x. 44.
[g] Black.
* Pure soda.
[h] Julin, Crell's *Annals*, 1797, ii. 373.
[i] Jahn, Ibid. i. 331.
[k] Schmeisser, *Phil. Trans.* lxxxii. 127.

CHAP. IV.

OF THE METHOD OF ANALYSING WATERS.

THE analysis of waters, or the art of ascertaining the different substances which they hold in solution, and of determining the proportion of these substances, is one of the most difficult things in chemistry. The difficulty arises, not only from the diversity of the bodies which occur in waters, but from the very minute quantities of some of the ingredients. Though many attempts had been made to analyse particular waters, and several of these were remarkably well conducted, no general mode of analysis was known till Bergman published his Treatise on Mineral Waters in 1778. This admirable tract carried the subject all at once to a very high degree of perfection. The Bergmannian method has been followed by succeeding chemists, to whom we are indebted not only for a great number of very accurate analyses of mineral waters, but likewise for several improvements in the mode of conducting the analysis. Mr Kirwan has in 1799 published an Essay on the general analysis of waters, no less valuable than that of Bergman; containing all that has hitherto been done on the subject, and enriched by the numerous experiments of Mr Kirwan himself, which are equally important and well conducted. Mr Kirwan has given a new method of analysis, which will probably be adopted hereafter; not only because it is shorter and easier than the Bergmannian, but because it is susceptible of a greater degree of accuracy. I propose in this Chapter to give an account of this method.

The analysis of waters resolves itself into two different branches: 1. The method of ascertaining all the different bodies contained in the water which we are examining. 2. The method of determining the exact proportion of each of these ingredients. These two branches shall form the subject of the two following Sections.

SECT. I.

METHOD OF DETERMINING THE INGREDIENTS OF WATERS.

Tests

THE different bodies which are dissolved and combined in water, are discovered by the addition of certain substances to the water which is subjected to examination. The consequence of the addition is some change in the appearance of the water; and this change indicates the presence or the absence of the bodies suspected. The substances thus employed are distinguished by the name of *tests*, and are the instruments by means of which the analysis of water is accomplished. They were first introduced into chemistry by Boyle, and were gradually increased by succeeding chemists: but Bergman was the first who ascertained with precision the degree of confidence which can be placed in the different tests. They still continued rather uncertain and precarious, till Mr Kirwan shewed how they might be combined and arranged in such a manner as to give certain and precise indications whether or not any particular substance constitutes a component part of water. Let us consider by what means the presence or the absence of all the different substances which occur in waters may be ascertained.

For gases,

I. The gaseous bodies contained in water are obtained by boiling it in a retort luted to a pneumatic apparatus. The method of separating and examining these different bodies shall be described in the next Section.

Carbonic acid,

II. The presence of *carbonic acid*, not combined with a base, or combined in excess, may be detected by the following tests: 1. Lime water occasions a precipitate soluble with effervescence in muriatic acid. 2. The infusion of litmus is *reddened;* but the red colour gradually disappears, and may be again restored by the addition of more of the mineral water *. 3. When boiled it loses the property of reddening the infusion of litmus.

Mineral acids,

III. The mineral acids when present, uncombined in water, give the infusion of litmus a permanent red, even though the water has been boiled. Bergman has shewn that paper, stained with litmus, is reddened when dipt into water containing $\frac{1}{3521}$ of sulphuric acid.

Sulphurated hydrogen,

IV. Water containing sulphurated hydrogen gas is distinguished by the following properties: 1. It exhales

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* When the carbonic acid is uncombined with a base, it reddens the infusion of litmus, though it amounts to no more than one-sixteenth of the bulk of the water which contains it. When it is combined in excess with a base, it must amount to one-sixth of the bulk of the water to produce that effect.—See Kirwan on *Mineral Waters*, p. 35.

e peculiar odour of sulphurated hydrogen gas. 2. It eddens the infusion of litmus fugaciously. 3. It blackns paper dipt into a solution of lead, and precipitates e nitrat of silver black or brown.

Alkaline and earthy carbonats,

V. Alkalies, and *alkaline* and *earthy carbonats*, are istinguished by the following tests: 1. The infusion f turmeric, or paper stained with turmeric, is rendered *rown* by alkalies, or reddish-brown if the quantity be inute. This change is produced when the soda in aters amounts only to $\frac{}{2217}$ part[*]. 2. Paper staind with Brazil wood, or the infusion of Brazil wood, is endered blue: But this change is produced also by the lkaline and earthy carbonats. Bergman ascertained hat water containing $\frac{1}{9945}$ part of carbonat of soda reners paper stained with Brazil wood blue[†]. 3. Litmus aper reddened by vinegar is restored to its original lue colour. This change is produced by the alkaline nd earthy carbonats also. 4. When these changes are ugacious, we may conclude that the alkali is ammonia.

Fixed alkalies,

VI. Fixed alkalies exist in water which occasions a recipitate with muriat of magnesia after being boiled. Volatile alkali may be distinguished by the smell, or t may be obtained in the receiver by distilling a porion of the water gently, and then it may be distinguishd by the above tests.

Earthy and metallic carbonats,

VII. Earthy and metallic carbonats are precipitated

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[*] The same change is produced by lime-water; but pure lime very eldom indeed occurs in mineral waters. It is needless to observe, that he alkalies produce the same effect on turmeric, whether they be pure r in the state of carbonats. The earthy carbonats have no effect on urmeric.

[†] Sulphat of lime likewise renders Brazil wood blue.

by boiling the water containing them; except carbonat of magnesia, which is only precipitated imperfectly.

Iron,

VIII. Iron is discovered by the following tests: 1. The addition of tincture of nutgalls gives water containing iron a purple or black colour. This test indicates the presence of a very minute portion of iron. If the tincture has no effect upon the water after boiling, though it colours it before, the iron is in the state of a carbonat. The following observations of Westrum on the colour which iron gives to nutgalls, as modified by other bodies, deserve attention.

A violet indicates an alkaline carbonat or earthy salt.
Dark purple indicates other alkaline salts.
Purplish red indicates sulphurated hydrogen gas *.
Whitish and then black indicates sulphat of lime.

2. The prussian alkali occasions a blue precipitate in water containing iron. If an alkali be present, the blue precipitate does not appear unless the alkali be saturated with an acid.

Sulphuric acid,

IX. Sulphuric acid exists in waters which form a precipitate with the following saline solutions:

1. Muriat, nitrat, or acetite of barytes
2. . . . . strontian
3. . . . . lime
4. Nitrat or acetite of lead.

Of these the most powerful by far is muriat of barytes, which is capable of detecting the presence of sulphuric acid uncombined, when it does not exceed the millionth part of the water. Acetite of lead is next in point of power. The muriats are more powerful than the nitrats. The calcareous salts are least powerful. All

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* Or rather manganese, according to Kirwan.

hese tests are capable of indicating a much smaller roportion of uncombined sulphuric acid than when it s combined with a base *. To render muriat of bary-es a certain test of sulphuric acid, the following pre-autions must be observed: 1. The muriat must be di-uted. 2. The alkalies, or alkaline carbonats, if the vater contain any, must be previously saturated with nuriatic acid. 3. The precipitate must be insoluble in nuriatic acid. 4. If boracic acid be suspected, muriat f strontian must be tried, which is not precipitated by oracic acid. 5. The hydrosulphurets precipitate ba-ytic solution, but their presence is easily discovered by he smell.

Muriatic acid,

X. Muriatic acid is detected by nitrat of silver, vhich occasions a white precipitate, or a cloud in wa-er containing an exceedingly minute portion of this a-id. To render this test certain, the following precau-ions are necessary: 1. The alkalies or carbonats must e previously saturated with nitric acid. 2. Sulphuric cid, if any be present, must be previously removed by neans of nitrat of barytes. 3. The precipitate must e insoluble in nitric acid.

Boracic acid,

XI. Boracic acid is detected by means of acetite of ead, with which it forms a precipitate insoluble in cetous acid. But to render this test certain, the alka-ies and earths must be previously saturated with acetous cid, and the sulphuric and muriatic acids removed by neans of acetite of strontian and acetite of silver.

Barytes,

XII. Barytes is detected by the insoluble white pre-ipitate which it forms with diluted sulphuric acid.

Lime,

XIII. Lime is detected by means of oxalic acid, which

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* Kirwan on *Mineral Waters*, p. 65.

occasions a white precipitate in water, containing a very minute proportion of this earth. To render this test decisive, the following precautions are necessary: 1. The mineral acids, if any be present, must be previously saturated with an alkali. 2. Barytes, if any be present, must be previously removed by means of sulphuric acid. 3. Oxalic acid precipitates magnesia but very slowly, whereas it precipitates lime instantly.

Magnesia and alumina,

XIV. Magnesia and alumina. The presence of these earths is ascertained by the following tests: 1. Pure ammonia precipitates them both, and no other earth, provided the carbonic acid has been previously separated by a mineral alkali and boiling. 2. Lime-water precipitates only these two earths, provided the carbonic acid be previously removed, and the sulphuric acid also, by means of nitrat of barytes.

The alumina may be separated from the magnesia after both have been precipitated together, either by boiling the precipitate in pure potass, which dissolves the alumina and leaves the magnesia; or the precipitate may be dissolved in muriatic acid precipitated by an alkaline carbonat, dried in the temperature of a 100°, and then exposed to the action of diluted muriatic acid, which dissolves the magnesia without touching the alumina.

Silica.

XV. Silica may be ascertained by evaporating a portion of the water to dryness, and redissolving the precipitate in muriatic acid. The silica remains behind undissolved.

Such is the method of detecting the different substances commonly found in waters. But as these different substances are almost always combined together, so as to constitute particular salts, it is not sufficient to know in eneral what the substances are which are found in the vater we are examining; we must know also in what anner they are combined. Thus it is not sufficient o know that lime forms an ingredient in a particular vater, we must know also the acid with which it is nited. Mr Kirwan first pointed out how to accomlish this difficult task by means of tests. Let us take short view of his method.

Sulphats.

I. To ascertain the presence of the different sulhats.

The sulphats which occur in water are seven, but ne of these, namely, *sulphat of copper*, is so uncomnon, that it may be excluded altogether. The same emark applies to sulphat of ammonia. It is almost unecessary to observe, that no sulphat need be looked for nless both its acid and base have been previously deected in the water.

1. Alkaline.

1. Sulphat of soda may be detected by the following nethod: Free the water to be examined of all earthy ulphats by evaporating it to one half, and adding lime-vater as long as any precipitate appears. By this means he earths will all be precipitated except lime, and the nly remaining earthy sulphat will be sulphat of lime, vhich will be separated by evaporating the liquid till t becomes concentrated, and then dropping into it a ittle alcohol, and after filtration adding a little oxalic cid.

With the water thus purified, mix a solution of lime. f a precipitate appears either immediately or on the ddition of a little alcohol, it is a proof that sulphat f potass or of soda is present. Which of the two may e determined by mixing some of the purified water vith acetite of barytes. Sulphat of barytes precipitates.

Filter and evaporate to dryness. Digest the residuum in alcohol. It will dissolve the alkaline acetite. Evaporate to dryness, and the dry salt will deliquesce if it be acetite of potass, but effloresce if it be acetite of soda.

2. Calcareous.

2. Sulphat of lime may be detected by evaporating the water suspected to contain it to a few ounces. A precipitate appears, which, if it be sulphat of lime, is soluble in 500 parts of water; and the solution affords a precipitate with the muriat of barytes, oxalic acid, carbonat of magnesia, and with alcohol.

3. Alum.

3. Alum may be detected by mixing carbonat of lime with the water suspected to contain it. If a precipitate appears it indicates the presence of alum, or at least of sulphat of alumina; provided the water contains no muriat of barytes or metallic sulphats. The first of these salts is incompatible with alum. The second may be removed by the alkaline prussiats. When a precipitate is produced in water by muriat of lime, carbonat of lime, and muriat of magnesia, we may conclude that it contains alum or sulphat of alumina.

4. Magnesian.

4. Sulphat of magnesia may be detected by means of hydrosulphuret of strontian, which occasions an immediate precipitate with this salt and with no other; provided the water be previously deprived of alum, if any be present, by means of carbonat of lime, and provided also that it contains no uncombined acid, not even carbonic acid.

5. Of iron.

5. Sulphat of iron is precipitated from water by alcohol, and then it may be easily recognised by its properties.

Muriats.

II. To ascertain the presence of the different muriats.

The muriats found in waters amount to eight or to

ne, if muriat of iron be included. The most common
far is muriat of soda.

1. Alkaline.

1. Muriat of soda and of potass may be detected by
e following method: Separate the sulphuric acid by
cohol and nitrat of barytes. Decompose the earthy
trats and muriats by adding sulphuric acid. Expel
e excess of muriatic and nitric acids by heat. Sepa-
te the sulphats thus formed by alcohol and barytic
ater. The water thus purified can contain nothing
it alkaline nitrats and muriats. If it forms a precipi-
te with acetite of silver, we may conclude that it con-
ins muriat of soda or of potass. To ascertain which,
aporate the liquid thus precipitated to dryness; dis-
lve the acetite in alcohol. Evaporate to dryness. The
lt will deliquesce if it be acetite of potass, but effloresce
it be acetite of soda.

2. Barytic.

2. Muriat of barytes may be detected by sulphuric
id, as it is the only barytic salt hitherto found in
aters.

3. Calcareous.

3. Muriat of lime may be detected by the following
ethod: Free the water of sulphat of lime and other
ilphats, by evaporating it to a few ounces, mixing it
ith spirit of wine, and adding last of all nitrat of
irytes as long as any precipitate appears. Filter off the
ater, evaporate to dryness, treat the dry mass with
cohol. Evaporate the alcohol to dryness and dissolve
ie residuum in water. If this solution gives a precipi-
ite with acetite of silver and oxalic acid, it *may* con-
in muriat of lime. It must contain it in that case,
, after being treated with carbonat of lime, it gives no
recipitate with ammonia. If it does, separate the lime
y means of oxalic acid, filter and distil with a gentle
eat. If the liquid in the receiver gives a precipitate with
itrat of silver, muriat of lime existed in the water.

4. Magnesian.

4. Muriat of magnesia may be detected by separating all the sulphuric acid by means of nitrat of barytes. Filter, evaporate to dryness, and treat the dry mass with alcohol. Evaporate the alcohol solution to dryness, and dissolve the residuum in water. The muriat of magnesia, if the water contained any, will be found in this solution. Let us suppose that, by the tests formerly described, the presence of muriatic acid and of magnesia in this solution has been ascertained. In that case, if carbonat of lime affords no precipitate, and if sulphuric acid and evaporation, together with the addition of a little alcohol, occasion no precipitate, the solution contains only muriat of magnesia. If these tests give precipitates, we must separate the lime which is present by sulphuric acid and spirit of wine, and distil off the acid with which it was combined. Then the magnesia is to be separated by the oxalic acid and alcohol; and the acid with which it was united is to be distilled off. If the liquid in the retort gives a precipitate with nitrat of silver, the water contains muriat of magnesia.

5. Aluminous.

5. Muriat of alumina may be discovered by saturating the water, if it contain an excess of alkali, with nitric acid, and separating the sulphuric acid by means of nitrat of barytes. If the liquid thus purified gives a precipitate with carbonat of lime, it contains muriat of alumina. The muriat of iron or of manganese, if any be present, is also decomposed, and the iron precipitated by this salt. The precipitate may be dissolved in muriatic acid, and the alumina, iron, and manganese, if they be present, may be separated by the rules laid down in the next Book.

Nitrats.

III. To ascertain the presence of the different nitrats.

The nitrats but seldom occur in waters; when they do, they may be detected by the following rules:

1. Alkaline. 1. Alkaline nitrats may be detected by freeing the water examined from sulphuric acid by means of acetite of barytes, and from muriatic acid by acetite of silver. Evaporate the filtered liquid, and treat the dry mass with alcohol; what the alcohol leaves can consist only of the alkaline nitrats and acetite of lime. Dissolve it in water. If carbonat of magnesia occasions a precipitate, lime is present. Separate the lime by means of carbonat of magnesia. Filter and evaporate to dryness, and treat the dried mass with alcohol. The alcohol now leaves only the alkaline nitrats, which may be easily recognised, and distinguished by their respective properties.

2. Calcareous. 2. Nitrat of lime. To detect this salt, concentrate the water, and mix it with alcohol to separate the sulphats. Filter and distil off the alcohol; then separate the muriatic acid by acetite of silver. Filter, evaporate to dryness, and dissolve the residuum in alcohol. Evaporate to dryness, and dissolve the dry mass in water. If this last solution indicates the presence of lime by the usual tests, the water contained nitrat of lime.

3. Magnesian. 3. To detect nitrat of magnesia, the water is to be freed from sulphats and muriats exactly as described in the last paragraph. The liquid thus purified is to be evaporated to dryness, and the residuum treated with alcohol. The alcohol solution is to be evaporated to dryness, and the dry mass dissolved in water. To this solution potass is to be added as long as any precipitate appears. The solution, filtered, and again evaporated to dryness, is to be treated with alcohol. If it leaves a residuum consisting of nitre (the only residuum

which it can leave), the water contained nitrat of magnesia.

Incompatible salts.

Such are the methods by which the presence of the different saline contents of waters may be ascertained. The labour of analysis may be considerably shortened, by observing that the following salts are incompatible with each other, and cannot exist together in water except in very minute proportions *.

SALTS.	INCOMPATIBLE WITH
1. Fixed alkaline sulphats	Nitrats of lime and magnesia, Muriats of lime and magnesia.
2. Sulphat of lime	Alkalies, Carbonat of magnesia, Muriat of barytes.
3. Alum	Alkalies, Muriat of barytes, Nitrat, muriat, carbonat of lime, Carbonat of magnesia.
4. Sulphat of magnenesia	Alkalies, Muriat of barytes, Nitrat and muriat of lime.
5. Sulphat of iron	Alkalies, Muriat of barytes, Earthy carbonats.
6. Muriat of barytes	Sulphats, Alkaline carbonats, Earthy carbonats.
7. Muriat of lime	Sulphats, except of lime, Alkaline carbonats, Carbonat of magnesia.

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* See Kirwan on *Mineral Waters*, passim.

Muriat of magnesia	Alkaline carbonats, Alkaline sulphats.
Nitrat of lime	Alkaline carbonats, Carb. of magn. and alumina, Sulphats, except of lime.

Besides the substances above described, there is ometimes found in water a quantity of bitumen comined with alkali, and in the state of soap. In such aters acids occasion a coagulation; and the coagulum ollected on a filter discovers its bituminous nature by s combustibility.

Water also sometimes contains *extractive matter*; the resence of which may be detected by means of nitrat f silver. The water suspected to contain it must be eed from sulphuric and nitric acid by means of niat of lead. After this, if it gives a brown precipitate ith nitrat of silver, we may conclude that extractive atter is present *.

SECT. II.

METHOD OF DETERMINING THE PROPORTION OF THE INGREDIENTS.

THE proportion of saline ingredients, held in solution y any water, may be in some measure estimated from s specific gravity. The lighter a water is, the less salne matter does it contain; and, on the other hand, the

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* Westrum.

heavier it is, the greater is the proportion of saline contents. Mr Kirwan has pointed out a very ingenious method of estimating the saline contents of a mineral water whose specific gravity is known; so that the error does not exceed one or two parts in the hundred. The method is this: Subtract the specific gravity of pure water from the specific gravity of the mineral water examined (both expressed in whole numbers), and multiply the remainder by 1.4. The product is the saline contents in a quantity of the water denoted by the number employed to indicate the specific gravity of distilled water. Thus let the water be of the specific gravity 1.079, or in whole numbers 1079. Then the specific gravity of distilled water will be 1000. And $\overline{1079 - 1000} \times 1.4 = 110.6 =$ saline contents in 1000 parts of the water in question; and consequently 11.06 in 100 parts of the same water *. This formula will often be of considerable use, as it serves as a kind of standard to which we may compare our analysis. The saline contents indicated by it are supposed to be freed from their water of crystallization; in which state only they ought to be considered, as Mr Kirwan has very properly observed, when we speak of the saline contents of a mineral water.

Formula for finding the saline contents of water.

Having by this formula ascertained pretty nearly the proportion of saline contents in the water examined, and having by the tests described in the last Section determined the particular substances which exist in it, let us now proceed to ascertain the proportion of each of these ingredients.

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* Kirwan on *Mineral Waters*, p. 145.

To estimate the gaseous bodies.

1. The different aerial fluids ought to be first sepa-
ted and estimated. For this purpose a retort ought
be filled two-thirds with the water, and connected
th a jar full of mercury, standing over a mercurial
ugh. Let the water be made to boil for a quarter
an hour. The aerial fluids will pass over into the
. When the apparatus is cool, the quantity of air
pelled from the water may be determined either by
nging the mercury within and without the jar to a
el; or if that cannot be done, by reducing the air to
proper density by the formulas given in the first
apter of the last Book. The air of the retort ought
be carefully subtracted, and the jar must be divided
o cubic inches and tenths.

The only gaseous bodies contained in water are com-
n air, oxygen gas, azotic gas, carbonic acid, sulphu-
ed hydrogen gas, and sulphurous acid. The last
o never exist in water together. The presence of
her of them must be ascertained previously by the
lication of the proper tests. If sulphurated hydrogen
be present, it will be mixed with the air contained
the glass jar, and must be separated before that air be
mined. For this purpose, the jar must be carried
a tub of warm water, and nitric acid introduced,
ich will absorb the sulphurated hydrogen. The re-
uum is then to be again put into a mercurial jar and
mined.

f the water contain sulphurous acid, this previous
p is not necessary. Introduce into the air a solution
nre potass, and agitate the whole gently. The car-
ic acid and sulphurous acid gas will be absorbed,
leave the other gases. Estimate the bulk of this
iduum; this, subtracted from the bulk of the whole,

will give the bulk of the carbonic acid and sulphurous acids absorbed.

Evaporate the potass slowly nearly to dryness, and leave it exposed to the atmosphere. Sulphat of potass will be formed, which may be separated by dissolving the carbonat of potass by means of diluted muriatic acid and filtering the solution. 100 grains of sulphat of potass indicate 30 grains of sulphurous acid, or 42.72 cubic inches of that acid in the state of gas. The bulk of sulphurous acid gas ascertained by this method, subtracted from the bulk of the gas absorbed by the potass, gives the bulk of the carbonic acid gas. Now 100 cubic inches of carbonic acid, at the temperature of 60° and barometer 30 inches, weigh 46.393 grains. Hence it is easy to ascertain its weight.

The air which remains after the separation of the carbonic acid gas is to be examined by the different eudiometrical methods described in the last Book.

When a water contains sulphurated hydrogen gas, the bulk of this gas is to be ascertained in the following manner: Fill three-fourths of a jar with the water to be examined, and invert it in a water trough, and introduce a little nitrous gas. This gas, mixing with the air in the upper part of the jar, will form nitrous acid, which will render the water turbid, by decomposing the sulphurated hydrogen and precipitating sulphur. Continue to add nitrous gas at intervals as long as red fumes appear, then turn up the jar and blow out the air. If the hepatic smell continues, repeat this process. The sulphur precipitated indicates the proportion of hepatic gas in the water; one grain of sulphur indicating the presence of 3.33 cubic inches of that gas.

II. After having estimated the gaseous bodies, the

Chap. IV.

To estimate the earthy carbonats.

xt step is to ascertain the proportions of the earthy rbonats. For this purpose it is necessary to deprive e water of its sulphurated hydrogen, if it contains y. This may be done, either by exposing it to the for a considerable time, or by treating it with li- arge. A sufficient quantity of the water thus purified necessary) is to be boiled for a quarter of an hour d filtered when cool. The earthy carbonats remain the filter.

The precipitate thus obtained may be carbonat of ne, of magnesia, of iron, of alumina; or even sulphat lime. Let us suppose all of these substances to be esent together. Treat the mixture with diluted mu- tic acid, which will dissolve the whole except the umina and sulphat of lime. Dry this residuum in a l heat, and note the weight. Then boil it in carbonat soda: saturate the soda with muriatic acid, and boil mixture for half an hour. Carbonat of lime and umina precipitate. Dry this precipitate, and treat it th acetous acid. The lime will be dissolved and the umina will remain. Dry it and weigh it. Its weight btracted from the original weight gives the propor- n of sulphat of lime.

The muriatic solution contains lime, magnesia, and n. Add ammonia as long as a reddish precipitate pears. The iron and part of the magnesia are thus parated. Dry the precipitate, and expose it to the for some time in a heat of 200°; then treat it with etous acid to dissolve the magnesia, which solution is be added to the muriatic solution. The iron is to redissolved in muriatic acid, precipitated by an alka- e carbonat dried and weighed.

Add sulphuric acid to the muriatic solution as long as any precipitate appears, then heat the solution and concentrate. Heat the sulphat of lime thus obtained to redness, and weigh it. 100 grains of it are equivalent to 70 of carbonat of lime dried. Precipitate the magnesia by means of carbonat of soda. Dry it and weigh it. But as part remains in solution, evaporate to dryness, and wash the residuum with a sufficient quantity of distilled water to dissolve the muriat of soda and the sulphat of lime, if any be still present. What remains behind is carbonat of magnesia. Weigh it, and add its weight to the former. The sulphat of lime, if any, must also be separated and weighed.

Estimation of the mineral acids,

III. Let us now consider the method of ascertaining the proportion of mineral acids or alkalies, if any be present uncombined. The acids which may be present (omitting the gaseous) are the sulphuric, muriatic, and boracic.

1. The proportion of sulphuric acid is easily determined. Saturate it with barytic water, and ignite the precipitate. 100 grains of sulphat of barytes thus formed indicate 23.5 of real sulphuric acid.

2. Saturate the muriatic acid with barytic water, and then precipitate the barytes by sulphuric acid. 100 parts of the ignited precipitate are equivalent to 21 grains of real muriatic acid.

3. Precipitate the boracic acid by means of acetite of lead. Decompose the borat of lead by boiling it in sulphuric acid. Evaporate to dryness. Dissolve the boracic acid in alcohol, and evaporate the solution; the acid left behind may be weighed.

And alkaline carbonats.

4. To estimate the proportion of alkaline carbonat present in a water containing it, saturate it with sulphuric acid, and note the weight of real acid necessary.

Now 100 grains of real sulphuric acid saturate 121.48 potass, and 78.32 soda.

To estimate sulphats.

IV. Let us now consider the method of ascertaining the proportion of the different sulphats. These are six in number; the alkaline sulphats, and those of lime, alumina, magnesia, and iron.

1. Alkaline,

1. The alkaline sulphats may be estimated by precipitating their acid by means of nitrat of barytes, having previously freed the water of all other sulphats. For 170 grains of ignited sulphat of barytes indicate 100 grains of dried sulphat of soda; while 136.36 grains of sulphat of barytes indicate 100 of dry sulphat of potass.

2. Calcareous,

2. Sulphat of lime is easily estimated by evaporating the liquid containing it to a few ounces (having previously saturated the earthy carbonats with nitric acid), and precipitating the sulphat of lime by means of weak alcohol. It may be then dried and weighed.

3. Aluminous,

3. The quantity of alum may be estimated by precipitating the alumina by carbonat of lime or of magnesia (if no lime be present in the liquid). Twelve grains of the alumina heated to incandescence indicate 100 of crystallized alum, or 49 of the dried salt.

4. Magnesian,

4. Sulphat of magnesia may be estimated, provided no other sulphat be present, by precipitating the acid by means of a barytic salt, as 100 parts of ignited sulphat of barytes indicate 52.11 of sulphat of magnesia. If sulphat of lime, and no other sulphat accompany it, this last may be decomposed, and the lime precipitated by carbonat of magnesia. The weight of the lime thus obtained enables to ascertain the quantity of sulphat of lime contained in the water. The whole sulphuric acid is then to be precipitated by barytes. This gives

the quantity of sulphuric acid; and subtracting the portion which belongs to the sulphat of lime, there remains that which was combined with the magnesia, from which the sulphat of magnesia may be easily estimated.

If sulphat of soda be present, no earthy nitrat or muriat can exist. Therefore, if no other earthy sulphat be present, the magnesia may be precipitated by soda, dried, and weighed; 36.68 grains of which indicate 100 grains of dried sulphat of magnesia. The same process succeeds when sulpat of lime accompanies these two sulphats; only in that case the precipitate, which consists both of lime and magnesia, is to be dissolved in sulphuric acid, evaporated to dryness, and treated with twice its weight of cold water, which dissolves the sulphat of magnesia, and leaves the other salt. Let the sulphat of magnesia be evaporated to dryness, exposed to a heat of 400°, and weighed. The same process succeeds if alum be present instead of sulphat of lime. The precipitate in that case, previously dried, is to be treated with acetous acid, which dissolves the magnesia, and leaves the alumina. The magnesia may be again precipitated, dried, and weighed. If sulphat of iron be present, it may be separated by exposing the water to the air for some days, and mixing with it a portion of alumina. Both the oxide of iron and the sulphat of alumina, thus formed, precipitate in the state of an insoluble powder. The sulphat of magnesia may then be estimated by the rules above explained.

5. Of iron.

5. Sulphat of iron may be estimated by precipitating the iron by means of prussic alkali, having previously determined the weight of the precipitate produced by the prussiat in a solution of a given weight of sulphat

f iron in water. If muriat of iron be also present, vhich is a very rare case, it may be separated by evaorating the water to dryness, treating the residuum ith alcohol, which dissolves the muriat, and leaves he sulphat. Or the sulphat may be estimated with reat precision by the rules laid down by Mr Kirwan*.

Estimation of muriats,

V. Let us now consider the method of estimating the uantity of the different muriats which may exist in aters.

1. Alkaline,

If muriat of potass or of soda, without any other lt, exist in water, we have only to decompose them y nitrat of silver, and dry the precipitate; for 217.65 f muriat of silver indicate 100 of muriat of potass, nd 235 of muriat of silver indicate 100 of common lt.

The same process is to be followed if the alkaline arbonats be present; only these carbonats must be reviously saturated with sulphuric acid; and we must recipitate the muriatic acid by means of sulphat of lver instead of nitrat. The presence of sulphat of oda does not injure the success of this process.

If muriat of ammonia accompany either of the fixed kaline sulphats without the presence of any other salt, ecompose the sal ammoniac by barytic water, expel e ammonia by boiling, precipitate the barytes by diited sulphuric acid, saturate the muriatic acid with oda. The sulphat of barytes thus precipitated indiates the quantity of muriat of ammonia; 100 grains f sulphur indicating 49.09 grains of that salt. If sulhats be present in the solution, they ought to be preiously separated.

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* *On Mineral Waters*, p. 220.

If common salt be accompanied by muriat of lime, muriat of magnesia, muriat of alumina, or muriat of iron, or by all of these together without any other salts, the earths may be precipitated by barytic water, and redissolved in muriatic acid. They are then to be separated from each other by the rules formerly laid down ; and their weight being determined indicates the quantity of every particular earthy muriat comtained in the water. For 50 grains of lime indicate 100 of dried muriat of lime ; 30 grains of magnesia indicate 100 of the muriat of that earth ; and 21.8 grains of alumina indicate 100 of the muriat of alumina The barytes is to be separated from the solution by sulphuric acid, and the muriatic acid expelled by heat, or saturated with soda ; the common salt may then be ascertained by evaporation, subtracting in the last case the proportion of common salt indicated by the known quantity of muriatic acid from which the earths had been separated.

When sulphats and muriats exist together, they ought to be separated either by precipitating the sulphats by means of alcohol, or by evaporating the whole to dryness, and dissolving the earthy muriats in alcohol. The salts thus separated may be estimated by the rules already laid down.

When alkaline and earthy muriats and sulphat of lime occur together, this last salt is to be decomposed by means of muriat of barytes. The precipitate ascertains the weight of sulphat of lime contained in the water. The estimation is then to be conducted as when nothing but muriats are present ; only from the muriat of lime that proportion of muriat must be deducted which is known to have been formed by the infusion of the muriat of barytes.

When muriats of soda, magnesia, and alumina, are present together with sulphats of lime and magnesia, the water to be examined ought to be divided into two equal portions. To the one portion add carbonat of magnesia till the whole of the lime and alumina be precipitated. Ascertain the quantity of lime which gives the proportion of sulphat of lime. Precipitate the sulphuric acid by muriat of barytes. This gives the quantity contained in the sulphat of magnesia and sulphat of lime; subtracting this last portion, we have the quantity of sulphat of magnesia.

From the second portion of water precipitate all the magnesia and alumina by means of lime-water. The weight of these earths enables us to ascertain the weight of muriat of magnesia and of alumina contained in the water, subtracting that part of the magnesia which existed in the state of sulphat, as indicated by the examination of the first portion of water. After this estimation precipitate the sulphuric acid by barytic acid, and the lime by carbonic acid. The liquid evaporated to dryness leaves the common salt.

Estimation of nitrats.

VI. It now only remains to explain the method of ascertaining the proportion of the nitrats which may exist in waters.

1. Alkaline,

1. When nitre accompanies sulphats and muriats without any other nitrat, the sulphats are to be decomposed by acetite of barytes, and the muriats by acetite of silver. The water, after filtration, is to be evaporated to dryness, and the residuum treated with alcohol, which dissolves the acetites, and leaves the nitre; the quantity of which may be easily estimated. If an alkali be present, it ought to be previously saturated with sulphuric or muriatic acid.

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2. Earthy.

2. If nitre, common salt, nitrat of lime, and muriat of lime or of magnesia, be present together, the water ought to be evaporated to dryness, and the dry mass treated with alcohol, which takes up the earthy salts. From the residuum, redissolved in water, the nitre may be separated, and estimated as in the last case. The alcohol solution is to be evaporated to dryness, and the residuum redissolved in water. Let us suppose it to contain muriat of magnesia, nitrat of lime, and muriat of lime. Precipitate the muriatic acid by nitrat of silver, which gives the proportion of muriat of magnesia and of lime. Separate the magnesia by means of carbonat of lime, and note its quantity. This gives us the quantity of muriat of magnesia. And subtracting the muriatic acid contained in that salt from the whole acid indicated by the precipitate of silver, we have the proportion of muriat of lime. Lastly, saturate the lime added to precipitate the magnesia with nitric acid. Then precipitate the whole of the lime by sulphuric acid; and subtracting from the whole of the sulphat thus formed that portion formed by the carbonat of lime added, and by the lime contained in the muriat, the residuum gives us the lime contained in the original nitrat; and 35 grains of lime form 100 of dry nitrat of lime.

BOOK III.

OF

MINERALS.

Book III.

ALL the solid materials of which this globe of ours is composed have received the name of *minerals*; and that branch of chemistry which treats of them is distinguished by the title of MINERALOGY. These substances without doubt must have at all times attracted the attention of mankind; because from them alone are drawn the metals, stones, and other similar substances of indispensable use. But it is only very lately that the method of ascertaining the component parts of these substances was discovered, or that it was possible to describe them so as to be intelligible to others. From the ancients no information of any consequence on these topics is to be expected. The whole science of mineralogy has been created since the year 1770, and is at present advancing towards perfection with astonishing rapidity. New minerals are every day described and analysed, collections are everywhere forming, and travels of discovery are succeeding each other without intermission. The fruit of these labours has been the discovery of no less than six new earths and eight new metals; besides a vast number of useful minerals which had been formerly unknown or disregarded.

The science of mineralogy includes under it three different topics: 1. The method of *describing* minerals with so much accuracy and precision, that they may be easily distinguished from each other. 2. *A systematic arrangement* of minerals. 3. The art of *analysing* minerals. These three topics shall form the subject of the three following Chapters.

CHAP. I.

OF THE DESCRIPTION OF MINERALS.

NOTHING, at first sight, appears easier than to describe a mineral, and yet, in reality, it is attended with a great deal of difficulty. The mineralogical descriptions of the ancients are so loose and inaccurate, that many of the minerals to which they allude cannot be ascertained; and consequently their observations, however valuable in themselves, are often, as far as respects us, altogether lost. It is obvious, that to distinguish a mineral from every other, we must either mention some peculiar property, or a collection of properties, which exist together in no other mineral. These properties must be described in terms rigidly accurate, which con-

Chap. I.

vey precise ideas of the very properties intended, and of no other properties. The smallest deviation from this would lead to confusion and uncertainty. Now it is impossible to describe minerals in this manner, unless there be a peculiar term for each of their properties, and unless this term be completely understood. Mineralogy therefore must have a language of its own; that is to say, it must have a *term* to denote every mineralogical property, and each of these terms must be accurately defined. The language of mineralogy was invented by the celebrated Werner of Freyberg, and first made known to the world by the publication of his treatise on *the external characters of minerals*. Of this language the following general description of the properties of minerals will convey an idea *.

Properties of minerals.

The properties of minerals may be divided into two classes. 1. Properties discoverable without destroying the texture of the mineral; 2. Properties resulting from the action of other bodies on it. The first class has, by Werner and his disciples, been called *external* properties, and by some French writers *physical*; the second class has been called *chemical*.

The *external* properties may be arranged under the following heads:

1. Figure.
2. Surface.
3. Transparency.
4. Colour.
5. Scratch.
6. Lustre.
7. Hardness.
8. Ductility.
9. Fracture.
10. Texture.
11. Structure.
12. Fragments.
13. Feel.
14. Sound.
15. Smell.
16. Taste.
17. Gravity.
18. Magnetism.
19. Electricity.

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* The fullest account of Werner's external characters which I have seen in the English language, has been given by Dr Townson in his *Philosophy of Mineralogy*.

Figure.

I. By FIGURE is meant the shape or form which a mineral is observed to have. The *figure* of minerals is either *regular*, *particular*, or *amorphous*. 1. Minerals which assume a regular figure are said to be crystallized. The *sides* of a crystal are called *faces*; the sharp line formed by the inclination of two faces is called an *edge*; and the corner, or angle, formed by the meeting of several edges in one point, is called a *solid angle*, or simply *an angle*. Thus a cube has six faces, twelve edges, and eight angles. 2. Some minerals, though not crystallized, affect a *particular* figure. These particular figures are the following: *Globular*, like a globe; *oval*, like an oblong spheroid; *ovate*, like an egg; *cheese-shaped*, a very flattened sphere; *almond-shaped*, like an almond; *lenticular*, like a double convex lense, compressed and gradually thinner towards the edges; *cuneiform*, like a wedge; *nodulous*, having depressions and protuberances like a potatoe; *botryoidal*, like grapes closely pressed together; *dentiform*, longish and tortuous, and thicker at the bottom than the top; *wireform*, like a wire; *capillary*, like hair, finer than the preceding; *retiform*, threads interwoven like a net; *dendritic*, like a tree, having branches issuing from a common stem; *shrubform*, branches not arising from a common stem; *coraloidal*, branched like coral; *stalactitical*, like isicles; *clavated*, like a club, long, and thicker at one end than another; *fasciform*, long straight cylindrical bodies, united like a bundle of rods; *tubular*, cylindrical and hollow. 3. When minerals have neither a regular nor particular shape, they are said to be *amorphous*.

Surface.

II. By SURFACE is meant the appearance of the external surface of minerals. The *surface* is either *uneven*, mposed of small unequal elevations and depressions ; *ibrous*, having very small *sharp* and rough elevations, re easily felt than seen; *drusy*, covered with very nute crystals ; *rough*, composed of very minute *blunt* vations, easily distinguishable by the feel; *scaly*, com- sed of very minute thin scale-like leaves; *smooth*, free m all inequality or roughness; *specular*, having a ooth polished surface like a mirror ; or *streaked*, ha- g elevated, straight, and parallel lines. This last cha- ter is confined to the *surface* of crystals. The *streaks* either *transverse ; longitudinal; alternate*, in diffe- nt directions on different faces; *plumose*, running from niddle rib ; or *decussated*, crossing each other.

Transparency.

III. By TRANSPARENCY is meant the proportion of ht which minerals are capable of transmitting. They *transparent* or *pellucid* when objects can be seen tinctly through them ; *diaphanous*, when objects are n through them indistinctly ; *subdiaphanous*, when ht passes but in so small a quantity that objects can- t be seen through them* ; *opaque*, when no light is nsmitted.

When opaque minerals become transparent in water, y are called *hydrophanous*. When objects are seen ble through a transparent mineral, it is said to *refract bly*.

Colours

IV. The colours of minerals may be reduced to eight sses.

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* According to Mr Kirwan's method, I have denoted these three de- es of transparency by the figures 4, 3, 2. When a mineral is subdia- nous only at the edges, that is denoted by the figure 1. Opacity is etimes denoted by 0.

Book III.

1. *Whites.*

Snow white. Pure white.
Reddish white. White with a light tint of red.
Yellowish white. White with a light tint of yellow.
Silver white. Yellowish white with a metallic lustre.
Greyish white. White with a light tint of black.
Greenish white. White with a light tint of green.
Milk white. White with a light tint of blue.
Tin white. Milk white of a metallic lustre.

2. *Greys.*

Bluish grey. Grey with a little blue.
Lead grey. Bluish grey with a metallic lustre.
Pearl grey. Light grey with a slight mixture of violet blue.
Smoke grey. Dark grey with a little blue and brown.
Greenish grey. Light grey tinged with green.
Yellowish grey. A light grey tinged with yellow.
Steel grey. A dark grey with a light tint of yellow and a metallic lustre.
Black grey. The darkest grey with a tint of yellow.

3. *Blacks.*

Greyish black. Black with a little white.
Brownish black. Black with a tint of brown.
Black. Pure black.
Iron black. Pure black with a small mixture of white and a metallic lustre.
Bluish black. Black with a tint of blue.

4. *Blues.*

Indigo blue. A dark blackish blue.
Prussian blue. The purest blue.
Azure blue. A bright blue with scarce a tint of red.

Smalt blue. A light blue.

Violet blue. A mixture of azure blue and carmine.

Lavender blue. Violet blue mixed with grey.

Sky blue. A light blue with a slight tint of green.

5. *Greens.*

Verdigris green. A bright green of a bluish cast.

Seagreen. A very light green, a mixture of verdi-s green and grey.

Beryl green. The preceding, but of a yellowish cast.

Emerald green. Pure green.

Grass green. Pure green with a tint of yellow.

Apple green. A light green formed of verdigris en and white.

Leek green. A very dark green with a cast of own.

Blackish green. The darkest green, a mixture of k green and black.

Pistachio green. Grass green, yellow and a little own.

Olive green. A pale yellowish green with a tint of own.

Asparagus green. The lightest green, yellowish with ittle brown and grey.

6. *Yellows.*

Sulphur yellow. A light greenish yellow.

Brass yellow. The preceding, with a little less green d a metallic lustre.

Lemon yellow. Pure yellow.

Gold yellow. The preceding with a metallic lustre.

Honey yellow. A deep yellow with a little reddish own.

Wax yellow. The preceding, but deeper.

Pyritaceous. A pale yellow with grey.

Straw yellow. A pale yellow, a mixture of sulphur yellow and reddish grey.

Wine yellow. A pale yellow with a tint of red.

Ochre yellow. Darker then the preceding, a mixture of lemon yellow with a little brown.

Isabella yellow. A pale brownish yellow, a mixture of pale orange with reddish brown.

Orange yellow. A bright reddish yellow, formed of lemon yellow and red.

7. *Reds.*

Aurora red. A bright yellow red, a mixture of scarlet and lemon yellow.

Hyacinth red. A high red like the preceding, but with a shade of brown.

Brick red. Lighter than the preceding, a mixture of aurora red and a little brown.

Scarlet red. A bright and high red with scarce a tint of yellow.

Copper red. A light yellowish red with the metallic lustre.

Blood red. A deep red, a mixture of crimson and scarlet.

Carmine red. Pure red verging towards a cast of blue.

Cochineal red. A deep red; a mixture of carmine with a little blue and a very little grey.

Crimson red. A deep red with a tint of blue.

Flesh red. A very pale red of the crimson kind.

Rose red. A pale red of the cochineal kind.

Peach blossom red. A very pale whitish red of the crimson kind.

Mordoré. A dark dirty crimson red; a mixture of crimson and a little brown.

Brownish red. A mixture of blood red and brown.

8. *Browns.*

Reddish Brown. A deep brown inclining to red.

Clove brown. A deep brown with a tint of carmine.

Yellowish brown. A light brown verging towards re yellow.

Umber brown. A light brown, a mixture of yelish brown and grey.

Hair brown. Intermediate between yellow brown clove brown with a tint of grey.

Tombac brown. A light yellowish brown, of a meic lustre, formed of gold yellow and reddish brown.

Liver brown. A dark brown; blackish brown with int of green.

Blackish brown. The darkest brown.

Colours, in respect of intensity, are either *dark*, *deep*, *ht*, or *pale*. When a colour cannot be referred to of the preceding, but is a mixture of two, this is ressed by saying, that the prevailing one *verges* tords the other, if it has only a small tint of it; *passes* o it, if it has a greater.

V. By the SCRATCH or STREAK, is meant the mark when a mineral is scratched by any hard body, as point of a knife. It is either *similar*, of the same our with the mineral; or *dissimilar*, of a different our.

Scratch.

VI. LUSTRE, is the gloss or brightness which aprs on the external surface of a mineral, or on its innal surface when fresh broken. The first is called *ernal*, the second *internal* lustre. Lustre is either *mon*, that which most minerals possess; *silky*, like t of silk or mother-of-pearl; *waxy*, like that of wax;

Lustre.

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greasy, like that of grease ; or *metallic*, like that of metals.

As to the degree, the greatest is called *splendent*, the next *shining*, the third *dullish ;* and when only a few scattered particles shine, the lustre is called *dull**.

Hardness.

VII. I have used Mr Kirwan's figures to denote the comparative HARDNESS of bodies ; for an explanation of which the reader is referred to Vol. I. p. 86. of this Work.

Ductility.

VIII. With respect to DUCTILITY and BRITTLENESS, minerals are either *malleable; sectile*, capable of being cut without breaking, but not malleable ; *flexile*, capable of being bent, and when bent retaining their shape ; or *elastic*, capable of being bent, but recovering their former shape. Minerals destitute of these properties are *brittle*. Brittle minerals, with respect to the ease with which they may be broken, are either *very tough*, *tough*, *fragile*, or *very fragile*.

Fracture.

IX. By FRACTURE is meant the fresh surface which a mineral displays when broken. It is either *flat*, without any general elevation or depression ; or *conchoidal*, having wide extended roundish hollows and gentle risings. When these are not *very* evident, the fracture is called *flat* conchoidal ; when they are small, it is called *small* conchoidal ; and when of great extent, *great* conchoidal.

The fracture may also be *even*, free from all asperities ; *uneven*, having many small, sharp, abrupt, irregular elevations and inequalities ; and from the size of these, this fracture is denominated *coarse*, *small*, or *fine ;*

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* These four degrees have been denoted by Mr Kirwan by the figures 4, 3, 2, 1, and no lustre by 0.

Chap. I.

lintery, having small, thin, half detached, sharp edged linters, according to the size of which this fracture is nominated *coarse* or *fine*; or *rugged*, having many ry minute sharp hooks, more sensible to the hand n the eye.

Texture.

X. By TEXTURE is meant the internal structure or sposition of the matter of which a mineral is compod, which may be discovered by breaking it. The xture is either *compact*, without any distinguishable rts, or the appearance of being composed of smaller rts; *earthy*, composed of very minute *almost* imperptible rough parts; *granular*, composed of small apeless grains; *globuliform*, composed of small sphecal bodies; *fibrous*, composed of fibres which may be *ng*, *short*, *straight*, *crooked*, *parallel*, *divergent*, *stellad*, *fasciculated*, or *decussated*; *radiated*, consisting of ng narrow flattish lamellæ; or *lamellar*, or *foliated*, nsisting of smooth continued plates covering each ther: these plates may be either *straight*, *crooked*, or *ndulating*.

Structure.

XI. The STRUCTURE or COMPOUND TEXTURE is the anner in which the parts that form the texture are isposed. It is either *slaty*, in straight layers like slate; *staceous*, in incurvated layers; *concentric*, in concenric layers; or *columnar*, in columns.

The *texture* and *structure* may at first view appear he same; but in reality they are very different. Thus ommon slate has often the *slaty structure* and *earthy exture*. The texture of pitcoal is compact, but its tructure is often slaty.

Fragments.

XII. By FRAGMENTS is meant the shape of the pieces nto which a mineral breaks when struck with a hammer. They are either *cubic*; *rhomboidal*; *wedgesha-*

ped; *splintery*, thin, long, and pointed; *tabular*, thin, and broad, and sharp at the corners, as common slate; or *indeterminate*, without any particular resemblance to any other body. The *edges* of indeterminate fragments are either *very sharp*, *sharp*, *sharpish*, or *blunt*.

Feel.

XIII. By the FEEL of minerals is meant the sensation which their surfaces communicate when handled. The feel of some minerals is *greasy*, of others *dry*, &c.

Sound.

XIV. Some minerals when struck give a *clear* SOUND, as common slate; others a *dull* sound.

The SMELL, TASTE, SPECIFIC GRAVITY, and MAGNETISM of minerals, require no explanation.

With respect to ELECTRICITY, some minerals become electric when *heated*, others when *rubbed*, others cannot be rendered electric. The electricity of some minerals is *positive* or *vitreous*, of others *negative* or *resinous*.

Of the blow-pipe.

The CHEMICAL properties of minerals will be understood without any explanation. In detecting them, the *blow-pipe* is often of singular use, as it enables us in a few minutes to determine many points which by the usual processes would occupy a great deal of time. The blow-pipe is merely a tube ending in a cavity as fine as a small wire, through which air is forced and made to play upon the flame of a candle, by means of which the flame is concentrated and directed against small particles of the mineral to be examined, either placed upon a bit of charcoal or in a platinum or silver spoon. The air is either forced into the blow-pipe by the lungs of the experimenter, or by means of bellows attached to the blow-pipe. By thus exposing a very small portion of a mineral to the concentrated flame, we see the effect of heat upon it, and have an opportunity of trying the action of other bodies on it at a very high emperature, as of borax, soda, microcosmic salt, &c. The properties which these experiments bring into iew, enable us in many cases to ascertain the nature, nd even the component parts, of a mineral.

The blow-pipe was first introduced into mineralogy y Von Swab. It was afterwards improved by Crontedt, and still farther by Bergman. Saussure substiuted a fine splinter of cyanite for charcoal, cemented a ery minute portion of the mineral to be examined to he point of this splinter, and exposed it in that situaion to the action of the blow-pipe. By this contriance he was enabled to make his experiments upon ery minute particles; and this enabled him to fuse any bodies formerly considered as infusible.

CHAP. II.

SYSTEM OF MINERALOGY.

Minerals may be arranged two ways, according to their external characters, and according to their chemical composition. The first of these methods has been called an *artificial* classification; the second, a *natural* one. The first is indispensably necessary for the student of nature; the second is no less indispensable for the proficient who means to turn his knowledge to account. Without the first, it is impossible to discover the *names* of minerals; and without the second, we must remain ignorant of their use.

Almost every system of mineralogy hitherto published, at least since the appearance of Werner's *external characters*, has attempted to combine these two arrangements, and to obtain at one and the same time the advantages peculiar to each. But no attempt of this kind has hitherto succeeded. Whether this be owing to any thing impossible in the undertaking, or to the present imperfect state of mineralogy, as is more probable, I do not take upon me to determine. But surely the want of success which has hitherto attended all attempts to combine the two arrangements, ought to suggest the propriety of separating them. By adhering strictly to one language, the trouble of studying two ifferent systems would be entirely prevented. They vould throw mutual light upon each other: the arti- cial system would enable the student to discover the *ames* of minerals; the natural would enable him to arrange them, and to study their properties and uses.

The happy arrangement of Cronstedt, together with the subsequent improvements of Bergman, Werner, Kirwan, Hauy, and other celebrated mineralogists, has brought the *natural* system of mineralogy to a considerable degree of perfection. But an *artificial* system is still a desideratum; for excepting Linnæus, whose uccess was precluded by the state of the science, no one has hitherto attempted it. I have elsewhere given an outline of an *artificial system*, extremely imperfect ndeed, but capable, by a combination with the Wernerian characters, of being made as precise as we please*. But such a system would be foreign to the present Work, in which our object ought certainly to be to arrange minerals according to their composition, or to give what has been called a *natural* system of mineralogy.

Division of minerals

Avicenna, a writer of the 11th century, divided minerals into four classes; stones, salts, inflammable bodies, and metals†. This division has been, in some measure, followed by all succeeding writers. Linnæus, indeed, the first of the moderns who published a system

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[*] See the *Supplement to the Encyclopædia Britannica*, vol. ii. p. 193.

[†] Corpora mineralia in quatuor species dividuntur, scilicet in lapides, et in liquefactiva, sulphurea, et sales. Et horum quædam sunt raræ substantiæ et debilis compositionis, et quædam fortis substantiæ, et quædam ductibilia, et quædam non. Avicenna *de Congelatione et Conglutinatione Lapidum*, cap. iii. *Theatrum Chemicum*, t. iv. p. 997.

of mineralogy, being guided by the external characters alone, divided minerals into three classes, *petræ*, *mineræ*, *fossilia* : but Avicenna's classes appear among his orders. The same remark may be made with respect to the systems of Wallerius, Wolsterdorf, Cartheuser, and Justi, which appeared in succession after the first publication of Linnæus's *Systema Naturæ*, in 1736. At last, in 1758, the system of Cronstedt appeared. He reinstated the classes of Avicenna in their place; and his system was adopted by Bergman, Kirwan, Werner, and the most celebrated mineralogists who have written since. These classes shall be adopted in the following system, because none which are preferable have been hitherto proposed.

Into classes.

I shall therefore divide minerals into four classes:

1. Stones,
3. Combustibles,
2. Salts.
4. Ores.

The first class comprehends all the minerals which are composed chiefly or entirely of earths; the second, all the combinations of acids and alkalies which occur in the mineral kingdom; the third, those minerals which are capable of combustion, and which consist chiefly of sulphur, carbon, and oil; the fourth, the mineral bodies which are composed chiefly of metals.

CLASS I.

EARTHS AND STONES.

This class may be divided into three orders. The first order comprehends all chemical combinations of earths with each other; the second order, chemical combinations of earths with acids; and the third order, mechanical mixtures of earths or stones. All the minerals belonging to the first order exhibit the same homogeneous appearance to the eye as if they were simple bodies. I shall therefore, for want of a better name, call the first order *simple*; the second order may be distinguished by the epithet of *saline*; and the third by that of *aggregates*; because most of the minerals belonging to it consist of various *simple stones*, cemented as it were together.

ORDER I. SIMPLE STONES.

Cronstedt's genera

Cronstedt divided this order into nine genera, corresponding to nine earths; one of which he thought composed the stones arranged under each genus. The names of his genera were, *calcariæ*, *siliceæ*, *granatinæ*, *argillaceæ*, *micaceæ fluores*, *asbestinæ*, *zeolithicæ*, *magnesiæ*. All his earths were afterwards found to be compounds, except the first, second, fourth, and ninth. Bergman, therefore, in his *Sciagraphia*, first published in 1782, reduced the number of genera to five; which was the number of primitive earths known when he wrote. Since that period five new earths have been discovered. Accordingly, in the latest systems of mineralogy, the genera belonging to this order are proportionally increased. Each genus is named from an earth; and they are arranged in the newest Wernerian system, which I have seen, as follows:

1. Jargon genus,
2. Siliceous genus,
3. Glucina genus,
4. Argillaceous genus,
5. Magnesian genus,
6. Calcareous genus,
7. Barytic genus,
8. Strontian genus.

Mr Kirwan, in his very valuable system of mineralogy, has adopted the same genera. Under each genus, those stones are placed which are composed chiefly of the earth which gives a name to the genus, or which at least are supposed to possess the characters which distinguish that earth.

Defective.

A little consideration will be sufficient to discover that there is no natural foundation for these genera. Most stones are composed of two, three, or even four ingredients; and, in many cases, the proportion of two or more of these is nearly equal. Now, under what genus soever such minerals are arranged, the earth which gives it a name must form the smallest part of their composition. Accordingly, it has not been so much the chemical composition, as the external character, which has guided the mineralogist in the distribution of his species. The genera cannot be said properly to have any character at all, nor the species to be connected by any thing else than an arbitrary title. This defect,

Class I.
Order I.

which must be apparent in the most valuable systems of mineralogy, seems to have arisen chiefly from an attempt to combine together an artificial and natural system. I have ventured to form new genera for this order, according to the following rules.

New genera.

The only substances which enter into the minerals belonging to this order, in such quantity as to deserve attention, are the following:

Alumina,
Silica,
Magnesia,
Lime,
Barytes,
Glucina,
Zirconia,
Yttria,
Oxide of iron,
Oxide of chromum,
Oxide of nickel,
Potass.

All those minerals which are composed of the *same* ingredients I arrange under the *same* genus. According to this plan, there must be as many genera as there are varieties of combinations of the above substances existing in nature. The varieties in the *proportion* of the ingredients constitute species. I have not imposed names upon these genera, but, in imitation of Bergman[*], have denoted each by a symbol. This symbol is composed of the first letter of every substance which enters in any considerable quantity into the composition of the minerals arranged under the genus denoted by it. Thus, suppose the minerals of a genus to be composed of *alumina*, *silica*, and *oxide of iron*, I denote the genus by the symbol *asi*. The letters are arranged according to the proportion of the ingredients; that which enters in the greatest proportion being put first, and the others in their order. Thus the genus *asi*

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[*] *Opusc.* iv. 231.

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Chap. II.

is composed of a considerable proportion of alumina, of a smaller proportion of silica, and contains least of all of iron. By this contrivance, the symbol of a genus contains, within the compass of a few letters, a pretty accurate description of its nature and character. Where the proportions of the ingredients vary in the same genus so much, that the letters which constitute its symbol change their place, I subdivide the genus into parts; and whenever the minerals belonging to any genus become too numerous, advantage may be taken of these subdivisions, and each of them may be formed into a separate genus. At present this seems unnecessary.

The following is a view of the different genera belonging to this order, denoted each by its symbol. Every genus is followed by the species included under it; and the whole are in the order which I mean to follow in describing them:

I. A.
1. Sapphire
2. Corundum
3. Native alumina
II. S.
1. Quartz
2. Flint
3. Opal
4. Pitchstone
5. Chrysoprasium
III. L.
Native lime
IV. AMC
Ruby
V. AIM
Ceylanite

VI. 1. As
1. Topaz
2. Sommite
3. Shorlite
2. SA
4. Rubellite
5. Hornslate
6. Hornstone
7. Chalcedony
8. Jasper
9. Tripoli
VII. ASI
1. 1. Micarell
2. Sharl
3. Granatite
2. SAI

Class I.
Order I.

4. Tourmaline
5. Argentine felspar
6. Mica
7. Talc
8. Basaltine
9. Hornblende
10. Obsidian
11. Petrilite
12. Felsite
III. Snaw
Pimelite
X. Sap
1. Felspar
2. Lepidolite
3. Leucite
4. White chlorite
. Sag
1. Emerald
2. Euclase
I. Sab
Staurolite
II. 1. Asl
1. Chrysoberyl
2. SAL
2. Hyalite
3. Edelite
4. Scapolite
3. SAWL
5. Zeolite
6. Stilbite
7. Chabasie
8. Analcime

4. SLA
9. Lazulite
XIII. Sali
1. Garnet
2. Pyrop
3. Melanite
4. Thummerstone
5. Prehnite
6. Thallite
7. Skorza
XIV. Ams
1. Cyanite
2. MSA
2. Serpentine
XV. Msai
1. Potstone
2. Chlorite
XVI. Slam
Siliceous spar
XVII. Samli
Argillite
XVIII. Slacmi
Smaragdite
XIX. Sm
1. Kiffekill
2. Steatites
XX. Msi
1. Chrysolite
2. Jade
XXI. Sml
1. Asbestus
2. Asbestinite

Class I.
Order I.

XXII. 1. Silm
1. Augite
2. Asbestoid
2. Smil
3. Actinolite
4. Idocrase

XXIII. Sl
1. Shistose hornstone
2. Tremolite
XXIV. Zs
Zircon
XXV. Ysi
Gadolinite

Genus I. A.

Sp. 1. Sapphire[*].

Oriental ruby, sapphire, and *topaz*—*Rubis d'orient* of Romé de Lisle—*Telesia* of Hauy—*Sapphire* of Delametherie.

History.

Three stones, distinguished from each other by their colour, have been long held in high estimation on account of their hardness and beauty. These stones were known among lapidaries by the names of *ruby, sapphire,* and *topaz*; and the epithet *oriental* was usually added, to distinguish them from other three, known by the same names and the same colours, but very inferior in hardness and beauty. Mineralogists were accustomed to consider these stones as three distinct species, till Romé de Lisle observed that they agreed in the form of their crystals, their hardness, and most of their other properties. These observations were sufficient to constitute them one species; and accordingly they were made one species by Romé de Lisle himself, by Kirwan, and several other modern mineralogical writers. Romé de Lisle gave the species the name of *ruby*; but this has

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[*] See Kirwan's *Mineralogy*, i. 250.—Gmelin's *Systema Naturæ* of Linnæus, iii. 170.—Romé de Lisle's *Crystallographie*, ii. 212.—Bergman's *Opuscula*, ii. 72.

Genus I. A.
Species I.

been since confined to a different mineral. This induced Hauy to invent the new word *telesia*; but the term *sapphire*, which has been appropriated to this species by Werner and Delametherie, has been adopted by mineralogists in general. I shall therefore use it in preference.

Crystals.

The sapphire is found in the East Indies, especially in Pegu and the island of Ceylon; and it is most commonly crystallized. The crystals are of no great size: Their *primitive* form, according to Mr Hauy, is a regular six-sided prism, divisible in directions parallel both to its bases and its sides; and consequently giving for the form of its primitive nucleus, or of its *integrant molecule*, an equilateral three-sided prism [*]. The most usual variety is a dodecahedron, in which the telesia appears under the form of two very long slender six-sided pyramids, joined base to base. The sides of these pyramids are isosceles triangles, having the angle at their vertex 22° 54′, and each of these at the base 78° 48′ [†]. The inclination of a side of one pyramid to a contiguous side of the other pyramid is 139° 54′ [‡]. In some specimens the summits of the pyramids are wanting; so that the crystal has the appearance of a six-sided prism, somewhat thicker in the middle than towards the extremities. The three alternate angles at each extremity of this prism are also sometimes wanting, and a small triangular face instead of them, which renders the bases of the supposed prism nine-sided. The inclina-

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[*] *Ann. de Chim.* xvii. 313.

[†] In some instances, the angle at the vertex is 31°, those at the base 74° 30′, and the inclination of two triangles 122° 36′. See Hauy, Ibid.

[‡] Ibid. and Romé de Lisle, ii. 315.

tion of each of these small triangles to the base is 122° 18′[*]. For figures of these crystals the reader is referred to Romé de Lisle and Hauy[†].

Properties.

The texture of the sapphire is foliated, and the joints are parallel to the base of the prism[‡]. Its lustre varies from 3 to 4[§]. Transparency usually 3 or 4, sometimes only 2. It causes only a single refraction. Specific gravity from 4. to 4.288. Hardness from 15 to 17. It is either colourless, or red, yellow, or blue. These colours have induced lapidaries to divide the species into the three following varieties.

Varieties.

Variety 1. Red. *Oriental ruby.*—Colour carmine red, sometimes verging towards violet. Sometimes various colours appear in the same stone, as red and white, red and blue, orange red. Hardness 17. Specific gravity 4.288.

Variety 2. Yellow. *Oriental topaz.*—Colour golden yellow. Transparency 4. Hardness 15. Specific gravity 4.0106.

Variety 3. Blue. *Oriental sapphire.*—Colour Berlin blue, often so very faint that the stone appears almost colourless. Transparency 3, 4, 2. Hardness 17. Specific gravity 3.991 to 4.083[‖]. This variety is not probably the same with the sapphire of the ancients. Their sapphire was distinguished by gold-coloured spots, none of which are to be seen in the sapphire of the moderns[¶].

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[*] Hauy, *Ann. de Chim.* xvii. 313. [†] Ibid. [‡] Hauy.

[§] When the *kind* of lustre is not specified, as in the present instance, the *common* is always meant.

[‖] Greville, Nicholson's *Journal*, iii. 11.

[¶] Hill's Theophrastus, περι των λιθων, p. 100.

Genus I. A.
Species I.

Composition.

A specimen of this last variety, analysed by Mr Klaproth, was found to contain in 100 parts,

98.5 alumina
1.0 oxide of iron
0.5 lime

100.0[*]

The colouring matter of all these varieties is, according to Bergman's experiments, iron, in different states of oxidation. He found that the topaz contained .06, he ruby .1, and the sapphire .02 of that metal[†]. But vhen these experiments were made, the analysis of stones ad not arrived at a sufficient degree of perfection to nsure accuracy. No conclusion, therefore, can be lrawn from these experiments, even though we were ertain that they were made upon the real varieties of he sapphire.

Sp. 2. Corundum[†].

Corundum of Gmelin—*Adamantine spar* of Klaproth and Kirwan—*Corindon* of Hauy—*Corivindum* of Woodward.

History.

This stone, though it appears to have been known to Ir Woodward, may be said to have been first distinuished from other minerals by Dr Black. In 1768, Ir Berry, a lapidary in Edinburgh, received a box of from Dr Anderson of Madras. Dr Black ascertaind that these specimens differed from all the stones

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[*] Beitrage, i. 81. [†] Bergman, ii. 96.

[‡] See Kirwan's *Min.* i.—Klaproth *in Beob. der Berlin*, viii. 295. and eitrage, i. 47.—Mr Greville and the Count de Bournon in the *Philosohical Transactions* 1798, p. 403. and in Nicholson's *Jour.* ii. 540. and iii. 5. -Mr Hauy, *Jour. de Phys.* xxx. 193. and *Jour. de Min.* No. xxviii. 262.

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Order I.

known to Europeans; and, in consequence of its hardness, it obtained the name of *adamantine spar*. Notwithstanding this, it could scarcely be said to have been known to European mineralogists till Mr Greville of London, who has done so much to promote the science of mineralogy, obtained specimens of it, in 1784, from India, and distributed them among the most eminent chemists, in order to be analysed. Mr Greville also learned that its Indian name was Corundum. It is found in Indostan, not far from the river Cavery, which is south from Madras, in a rocky matrix, of considerable hardness, partaking of the nature of the stone itself[*]. It occurs also in China; and a substance, not unlike the matrix of corundum, has been found in Teree, one of the western islands of Scotland[†].

Crystals.

The corundum is usually crystallized. Its primitive form, discovered by Mr Hauy[‡] and the Count de Bournon[§], is a rhomboidal parallelopiped, whose sides are equal rhombs, with angles of 86° and 94°, according to Bournon, or whose diagonals are to each other as $\sqrt{17}$ to $\sqrt{15}$, according to Hauy; which is very nearly the same thing. The most common variety (for the primitive form has never yet been found) is the regular six-sided prism, the alternate angles of which are sometimes wanting, and the triangular faces, which occupy their place, are inclined to the base at an angle of 122° 34′[‖]. Sometimes the corundum is crystallized in the form of a six-sided pyramid, the apex of which is generally wanting. For a description and figure of these,

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[*] Garrow and Greville, *Nicholson's Jour.* ii. 540.

[†] Greville, Ibid

[‡] *Jour. de Min.* No. xxviii. 262.

[§] Nicholson's *Jour.* ii. 541

[‖] De Bournon.

Genus I. A.
Species II.

nd all the other varieties of corundum hitherto obser-ed, the reader is referred to the dissertation of the ount de Bournon on the subject*.

Properties.

The texture of the corundum is foliated, and the na-ural joints are parallel to the faces of the primitive homboidal parallelopiped. Lustre, when in the di-ection of the laminæ, 3; when broken across, 0. O-aque, except when in very thin pieces. Hardness 15 pecific gravity from 3.710 to 4.180†. Colour grey, ften with various shades of blue and green.

Composition.

According to the analysis of Klaproth, the corundum f India is composed of 89.5 alumina
5.5 silica
1.25 oxide of iron

96.25‡

A specimen from China of 84.0 alumina
6.5 silica
7.5 oxide of iron

98.0§

Notwithstanding the quantity of silica and of iron which these analyses exhibit in the corundum, I have been induced to include it in the present genus, on account of the strong resemblance between it and the third variety of the sapphire. The resemblance between the crystals of these minerals appears evident even from the short description given above: and the observations of Bournon|| render this resemblance

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* See also Hauy, *Jour. de Min.* No. xxviii. 262.

† Klaproth. See also Greville. Nicholson's *Jour.* iii. 11.

‡ Beitrage, i. 77.

§ Ibid. i. 73.

|| Nicholson's *Jour.* iii. 9.

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still more striking. It is not improbable, therefore, as Mr Greville and the Count de Bournon have suggested, that corundum may be only a variety of the sapphire; and that the seeming difference in their ingredients is owing to the impurity of those specimens of corundum which have hitherto been brought to Europe. Let not the difference which has been found in the primitive form of these stones be considered as an insuperable objection till the subject has been again examined with this precise object in view; for nothing is easier than to commit an oversight in such difficult examinations.

Sp. 3. Native alumina*.

This substance has been found at Halles in Saxony in compact kidney-form masses. Its consistence is earthy. Lustre 0. Opaque. Hardness 4. Brittle. Specific gravity moderate. Feels soft, but meagre. Adheres very slightly to the tongue. Stains very slightly. Colour pure white. Does not readily diffuse itself in water.

It consists of pure alumina mixed with a small quantity of carbonat of lime, and sometimes of sulphat of lime†.

GENUS II. S.

Sp. 1. Quartz‡.

This stone, which is very common in most mountainous countries, is sometimes crystallized, and sometimes amorphous. The primitive form of its crystals, according to Mr Hauy, is a rhomboidal parallelopiped; the

Crystals.

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* See Kirwan's *Min.* i. 175, and Schreber, 15 Stuck, p. 209.

† Schreber.

‡ Kirwan's *Min.* i. 241.

Genus II. S. Species I.

ngles of whose rhombs are 93° 22′ and 86° 38′; so hat it does not differ much from a cube *. The most ommon variety is a dodecahedron, composed of two ix-sided pyramids, applied base to base, whose sides are sosceles triangles, having the angle at the vertex 40°, nd each of the angles at the base 70 ; the inclinaion of a side of one pyramid to the contiguous side of he other pyramid is 104°. There is often a six-sided rism interposed between the two pyramids, the sides of hich always correspond with those of the pyramids §. or a description and figure of the other varieties of uartz crystals, and for a demonstration of the law hich they have followed in crystallizing, we refer the eader to *Romé de Lisle* § and *Mr Hauy* ||.

The texture of quartz is more or less foliated. Fracure, conchoidal or splintery. Its lustre varies from to 1, and its transparency from 4 to 1; and in some ses it is opaque. It causes a double refraction. Hardess, from 10 to 11. Specific gravity from 2.64 to .67, and in one variety 2.691. Its colour is exceedingly rious; a circumstance which has induced mineralogists divide it into numerous varieties. Of these the folwing are the chief:

Varieties.

1. Pure colourless, perfectly transparent crystallized uartz, having much the appearance of artificial crystal; nown by the name of *rock crystal*.

2. Quartz less transparent, and with a splintery fracre, has usually been distinguished by the name of *uartz*, and separated from rock crystal. As there is occasion for this separation, I have, in imitation of

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* *Jour. de Min.* No. xxviii. 255.

§ *Crystal.* ii. 71.

|| *Mem. Par.* 1786. p. 78. See also Lametherie, *Jour. de Phys.* xlii. 470.

Class I.
Order I.

Mr Hauy, chosen the word quartz for the *specific name*, comprehending under it all the varieties.

3. Blood red quartz; formerly called *compostella hyacinth*, and by Hauy *quartz hematoide*. It owes its colour to oxide of iron. The mineral known to mineralogists by the name of *sinople*, and considered by them as a variety of *jasper*, has been discovered by Dolomieu to be merely this variety of quartz in an amorphous state[*].

4. Yellow quartz; called false topaz.

5. Rosy red quartz; called Bohemian ruby.

For a fuller enumeration of these varieties, the reader is referred to *Smeisser's Mineralogy*[†] *Kirwan's Mineralogy*[‡], and Gmelin's edition of the *Systema Naturæ* of Linnæus[§]. This last writer, however, has arranged several minerals under quartz which do not belong to it.

Pure quartz is composed entirely of silica; but some of the varieties of this species are contaminated with metallic oxides, and with a small quantity of other earths.

Sp. 2. Elastic Quartz[‖].

This singular stone is moderately elastic, and flexible in every direction. Texture, earthy. Lustre, 0 or 1. Hardness, 9. Brittle. Specific gravity 2.624. Colour, greyish white. Phosphoresces when scraped with a knife in the dark. The specimen analysed by Mr Klaproth contained . . . 96.5 silica,
2.5 alumina,
5 oxide of iron,

99.5[¶]

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[*] *Jour. de Min.* No. xxviii. 255.
[†] i. 89.
[‡] i. 244.
[§] iii. 194.

[‖] Kirwan's *Min.* i. 316.—Gerhard *Mem. Berlin*, 1783. p. 107.—Klaproth's Beitrage 2 *Band.* 113. See also *Jour. de Phys.* xli. 91.

[¶] Beitrage, ii. 116.

Genus II. S.
Species III.

Sp. 3. Flint *.

Pyromachus—Pierre a fusil—Silex of Hauy.

Situation.

This stone, which has become so necessary in modern war, is found in pieces of different sizes, and usually of a figure more or less globular, commonly among chalk, and often arranged in some kind of order. In Saxony it is said to have been found crystallized in hexahedrons, composed of two low three-sided pyramids applied base to base †.

Properties.

Its texture is compact. Its fracture, smooth conchoidal. Lustre, external 0, the stones being always covered by a white crust; internal 1, inclining to greasy. Transparency, 2; when very thin, 3. Hardness, 10 or 11. Specific gravity, from 2.58 to 2.63. Colour varies from honey yellow to brownish black. Very brittle and splits into splinters in every direction. Two pieces of flint rubbed smartly together phosphoresce, and emit a peculiar odour. When heated it decrepitates, and becomes white and opaque. When exposed long to the air it often becomes covered with a white crust. A specimen of flint analysed by Klaproth contained

Composition.

contained	98.00	silica,
	.50	lime,
	.25	alumina,
	0.25	oxide of iron,
	1.00	water.
	100.00 ‡	

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* Kirwan's *Min.* i. 301.—Dolomieu, *Jour. de Min.* No. xxxiii. 693. and Salivet, ibid. 713. These last gentlemen give the only accurate account of the method of making gun flints.

† Gmelin's *Systema Naturæ*, iii. 183. ‡ Beitrage, i. 46.

Another specimen analysed by Dolomieu was composed of
97 silica,
1 alumina and oxide of iron,
2 water.

100[*]

The white crust with which flint is enveloped consists of the same ingredients, and also a little carbonat of lime. Dolomieu discovered that water is essential to flint; for when it is separated by heat the stone loses its properties[†].

Gun flints.

The manufacture of gun flints is chiefly confined to England and two or three departments in France. The operation is exceedingly simple: a good workman will make 1000 flints in a day. The whole art consists in striking the stone repeatedly with a kind of mallet, and bringing off at each stroke a splinter, sharp at one end and thicker at the other. These splinters are afterwards shaped at pleasure, by laying the line at which it is wished they should break, upon a sharp iron instrument, and then giving it repeatedly small blows with a mallet. During the whole operation the workman holds the stone in his hand, or merely supports it on his knee[‡].

Sp. 4. Opal[||].

Situation.

This stone is found in many parts of Europe, especially in Hungary, in the Crapacks near the village of Czennizka. When first dug out of the earth it is soft, but it hardens and diminishes in bulk by exposure to the air. The substance in which it is found is a ferrugenous sand-stone[§].

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[*] *Jour. de Min.* No. xxxiii. 702. [†] Ibid. [‡] Ibid.

[§] Delius, *Jour. de Phys.* xliv. 45.

[||] Kirwan's *Min.* i. 289.—Hauy, *Jour. de Hist. Nat.* ii. 9.—Delius, *Jour. de Phys.* xliv. 45.

Genus II. S. Species IV.

Properties.

The opal is usually amorphous. Its fracture is conhoidal, commonly somewhat transparent. Hardness rom 6 to 10. Specific gravity from 1.7 to 2.66. The owness of its specific gravity, in some cases, is to be scribed to accidental cavities which the stone contains. These are sometimes filled with drops of water. Some pecimens of opal have the property of emitting various oloured rays, with a particular effulgency, when placed between the eye and the light. The opals which possess his property are distinguished by lapidaries by the epithet *oriental;* and often by mineralogists by the epithet nobilis. This property rendered the stone much esteemed by the ancients. Opals acquire it by exposure o the sun.

Varieties.

Variety 1. *Oriental* or *noble.*—Lustre glassy, 3. Transparency, 3 to 2. Hardness, 6 to 8. Colour, usually light bluish white, sometimes yellow or green. When heated it becomes opaque, and sometimes is decomposed by the action of the atmosphere. Hence it seems to follow that water enters essentially into its composition. A specimen of this variety, analysed by Klaproth, contained

90 silica,
10 water.

100 *

Variety 2. Semi-opal.—Fracture, imperfectly conchoidal. Lustre, glassy 2. Transparency 2 to 3. Hardness, 7 to 9. Its colours are very various; greys, yellows, reds, browns, greens of different kinds.

Specimens of this variety sometimes occur with rifts: these readily imbibe water, and therefore adhere to the tongue. Some opals gradually become opaque, but re-

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* Beitrage, ii. 153.

Class I. Order I.

cover their transparency when soaked in water by imbibing that fluid. They are then called *hydrophanes*, or *oculi mundi.*

Variety 3. Cat's eye *.—This variety comes from Ceylon, and is seldom seen by European mineralogists till it has been polished by the lapidary. Mr Klaproth has described a specimen which he received in its natural state from Mr Greville of London. Its figure was nearly square, with sharp edges, a rough surface, and a good deal of brilliancy.

Its texture is imperfectly foliated. Lustre greasy, 2. Transparency 3 to 2. Hardness 10. Specific gravity 2.56 to 2.66. Colour grey; with a tinge of green, yellow, or white: or brown, with a tinge of yellow or red. In certain positions it reflects a splendid white, as does the eye of a cat; hence the name of this stone.

Two specimens, analysed by Klaproth, the first from Ceylon, the other from Malabar, were composed of

95.00	94.50	silica
1.75	2.00	alumina
1.50	1.50	lime
0.25	0.25	oxide of iron
98.5 †	98.25 ‡	

Sp. 5. Pitchstone §.

Menelites.

Situation.

This stone, which occurs in different parts of Germany, France, and other countries, has obtained its name from some resemblance which it has been supposed to have to pitch. It is most usually in amorphous pieces of different sizes; and it has been found also cry-

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* Kirwan's *Min.* i. 301.—Klaproth, Beitrage, i. 90.

† Beitrage, i. 94.

‡ Ibid. p. 96.

§ Kir. *Min.* i. 292.—Daubenton, *Mem. Par.* 1787, p. 86.

Genus II. S. Species V.

stallized in six-sided prisms, terminated by three-sided pyramids.

Properties.

Its fracture is conchoidal and uneven, and sometimes approaches the splintery. Lustre greasy, from 3 to 1. Transparency 2 to 1, sometimes 0. Hardness 8 to 10. Exceedingly brittle; it yields even to the nail of the finger. Specific gravity 2.049 to 2.39. Its colours are numerous, greyish black, bluish grey, green, red, yellow of different shades. Sometimes several of these colours appear together in the same stone. A specimen of pitch-stone from Mesnil-montant near Paris *, analysed by Mr Klaproth, contained

Composition.

85.5 silica
11.0 air and water
1.0 alumina
.5 iron
.5 lime and magnesia

98.5 †

Sp. 6. Chrysoprasium ‡.

This mineral, which is found in different parts of Germany, particularly near Kosemütz in Silesia, is always amorphous. Its fracture is either even or inclining to the splintery. Scarcely any lustre. Transparency 2 to 3. Hardness 10 to 12. Specific gravity 2.479. Colour green. In a heat of 130° Wedgewood it whitens and becomes opaque.

A specimen of this stone, analysed by Mr Klaproth, contained

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* See *Jour. de Phys.* xxxi. 219.

† Beitrage, ii. 169.

‡ Kirwan's *Min.* i.—Lehmann, *Mem. Berlin*, 1755, p. 202.—Klaproth, Beitrage, ii. 127.

Class I.
Order I.

96.16	silica
1.00	oxide of nickel
0.83	lime
0.08	alumina,
0.08	oxide of iron
98.15*	

Genus. III. L.

Sp. 1. Native Lime.

The existence of pure uncombined lime in a native state has been questioned; but the evidence on which the belief of its existence is founded is sufficiently respectable to put the matter beyond doubt. Monnet affirms that it exists in abundance in the mountains of Upper Auvergne, mixed, however, with a little oxide of iron†. Dr Falconer of Bath found a soft whitish mineral in the neighbourhood of that town, consisting partly of pure lime capable of dissolving sulphur‡, and from which lime-water may be made. I have been informed by his son Mr Thomas Falconer, that a gentleman who is at present collecting the minerals about Bath has found it, though not in any great quantity.

Genus IV. Amc.

Sp. 1. Ruby§.

Spinel and *balass Ruby* of Kirwan—*Ruby* of Hauy—*Rubis spinelle octoedre* of De Lisle—*Spinellus* of Gmelin.

This stone, which comes from the island of Ceylon,

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[*] Beitrage, ii. 133.

[†] Monnet's *Mineralogy*, p. 515.

[‡] *On Bath Waters*, p. 156.

[§] See Kirwan's *Min.* i. 253.—Romé de Lisle, ii. 224.—Klaproth *Beob. der Berlin*, iii. 336. and Beitrage, ii. 1.—Vauquelin *Ann. de Chim.* xxvii. 3. and xxxi. 141.

Genus IV. AMC. Species I.

Crystals.

is usually crystallized. The form of its integrant particles is the tetrahedron. The primitive form of its crystals is a regular octahedron, composed of two four-sided pyramids applied base to base, each of the sides of which is an equilateral triangle *. In some cases two opposite sides of the pyramids are broader than the other two; and sometimes the edges of the octahedron are wanting, and narrow faces in their place. For figures and descriptions of these, and other varieties of these crystals, the reader is referred to *Romé de Lisle* and the *Abbé Estner* †.

Properties.

The texture of the ruby is foliated. Its lustre is 3. Transparency 3 to 4. It causes a single refraction. Hardness 13. Specific gravity 3.570‡ to 3.625 §. Colour red; if deep, the ruby is usually called *balass*; if pale rosy, *spinell*.

Composition.

The ruby, according to the analysis of Vauquelin, is composed of

86.00	alumina,
8.50	magnesia,
5.25	chromic acid.
99.75 ‖	

The ancients seem to have classed this stone among their hyacinths ¶.

GENUS V. AIM.

Sp. 1. Ceylanite.

History.

The mineral denominated *ceylanite*, from the island of Ceylon, from which it was brought into Europe, had

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[*] This octahedron is usually distinguished either by the epithet *regular* or *aluminiform*, because it is the well-known form of crystals of alum.

[†] *Crystall.* ii. 226.—Estner's *Miner.* 73.

[‡] Klaproth.

[§] Hatchette and Greville.

[‖] *Ann. de Chim.* xxvii. 15.

[¶] Plinii, lib. xxxvii. c. 9.

Class I.
Order I.

been observed by Romé de Lisle[*]; but was first described by La Metherie in the Journal de Physique for January 1793.

Crystals.

It is most commonly found in rounded masses; but sometimes also crystallized. The primitive form of its crystals is a regular octahedron: it commonly occurs under this form, but more commonly the edges of the octahedron are wanting, and small faces in their place[†].

Properties.

The fracture of the ceylanite is conchoidal[‡]. Its internal lustre is glassy. Nearly opaque, except when in very thin pieces. Hardness 12. Specific gravity from 3.7647[§] to 3.793[||]. Colour of the mass, black; of very thin pieces, deep green. Powder, greenish grey.

Composition.

According to the analysis of Descotils the ceylanite is composed of
68 alumina,
16 oxide of iron,
12 magnesia,
2 silica.
———
98[¶]

GENUS VI. 1. As.

Sp. 1. Topaz[**].

Occidental ruby, *topaz*, and *sapphire*.

History.

The name *topaz* has been restricted by Mr Hauy to the stones called by mineralogists occidental ruby, topaz, and sapphire; which, agreeing in their crystallization and most of their properties, were arranged under one species by Mr Romé de Lisle. The word *topaz*, deri-

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[*] *Crystallog.* iii. 180. Note 21.

[†] Hauy, *Jour. de Min.* No. xxxviii. 264.

[‡] Ibid. 263.

[§] Hauy.

[||] Descotils.

[¶] *Ann. de Chim.* xxxiii. 113.

[**] Kirwan's *Min.* i. 254.—Pott. *Mem. Berlin*, 1747, p. 46.—Margraf, ibid. 1776. p. 73. and 160.—Henkel, *Act. Acad. Nat. Cur.* iv. 316.

Genus VI.
As.
Species I.

ved from an island in the Red Sea *, where the ancients used to find topazes, was applied by them to a mineral very different from ours. One variety of our topaz they denominated *chrysolite.*

The topaz is found in Saxony, Bohemia, Siberia, and Brazil, mixed with other minerals in granite rocks.

Crystals.

It is commonly crystallized. The primitive form of its crystals is a prism whose sides are rectangles and bases rhombs, having their greatest angles 124° 22′ and the integral molecule has the same form †; and the height of the prism is to a side of the rhomboidal bases as 3 to 2. The different varieties of topaz crystals hitherto observed amount to 6. Five of these are eight-sided prisms, terminated by four-sided pyramids, or wedge-shaped summits, or by irregular figures of 7, 13, or 15 sides; the last variety is a twelve-sided prism, terminated by six-sided pyramids wanting the apex. For an accurate description and figure of these varieties the reader is referred to Mr Hauy ‡.

Properties.

The texture of the topaz is foliated. Its lustre is from 2 to 4. Transparency from 2 to 4. It causes a double refraction. Hardness 12 to 14. Specific gravity from 3.5311 to 3.564. The Siberian and Brazil topazes, when heated, become positively electrified on one side, and negatively on the other §. It is infusible by the blow-pipe. The yellow topaz of Brazil becomes red when exposed to a strong heat in a crucible; that of Saxony becomes white by the same process.

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[*] It got its name from τοπαζω, to *seek;* because the island was often urrounded with fog, and therefore difficult to find. See Plinii, lib. xxvii. c. 8.

[†] Hauy, *Jour. de Min.* No. xxviii. 287.

[‡] *Jour. de Min.* ibid.

[§] Hauy, ibid.

Class I. Order I.

This shews us that the colouring matter of these two stones is different.

The colour of the topaz is various, which has induced mineralogists to divide it into the following varieties:

Varieties.

1. Red topaz, of a red colour, inclining to yellow; called *Brazilian* or *occidental ruby*.

2. Yellow topaz, of a golden yellow colour, and sometimes also nearly white; called *occidental* or *Brazil topaz*. The powder of this and the following variety causes syrup of violets to assume a green colour [*].

3. Saxon topaz. It is of a pale wine yellow colour, and sometimes greyish white.

4. Aigue marine. It is of a bluish or pale green colour.

5. Occidental sapphire. It is of a blue colour; and sometimes white.

A specimen of white Saxon topaz, analysed by Vauquelin, contained

68 alumina
31 silica

99 [†]

Sp. 2. Sommite.

Hexagonal white shorl of Ferber—*White hyacinth* of Somma.

This stone was called *sommite* by Lametherie, from the mountain Somma, where it was first found. It is usually mixed with volcanic productions. It crystallizes in six-sided prisms, sometimes terminated by pyramids. Colour white. Somewhat transparent. Cuts glass. Specific gravity 3.2741. Infusible by the blow-

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[*] Vauquelin, *Jour. de Min.* No. xxix. 165.

[†] Ibid. No. xxiv. 3.

Genus VI.
As.
Species III.

e. According to the analysis of Vauquelin, it is nposed of

49 alumina
46 silica
2 lime
1 oxide of iron .

98*

Sp. 3. Shorlite†.

This stone, which received its name from Mr Klaoth, is generally found in irregular oblong masses or umns, inserted in granite. Its texture is foliated. icture uneven. Lustre 2. Transparency 2 to 1. rdness 9 to 10. Specific gravity 3.53. Colour greenwhite, or sulphur yellow. Not altered by heat. Acding to the analysis of Klaproth, it is composed of

50 alumina
50 silica

100

GENUS VI. 2. SA.

Sp. 4. Rubellite ‡.—*Siberite* of Lermina.

Red shorl of Siberia—*Daourite* of Delametherie.

This stone is found in Siberia mixed with white artz. It is crystallized in small needles, which are uped together, and traverse the quartz in various ditions. Texture fibrous. Fracture glassy, inclining the conchoidal. Transparency 2; at the edges 3. rdness 10. Brittle. Specific gravity 3.048. Colour mson, blood, or peach red. By exposure to a red it it becomes snow white; but loses none of its

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* *Jour. de Min.* No. xxviii. 279.

† Kirwan's *Min.* i. 286.

‡ Kirwan's *Min.* i. 288.—Bindheim, Crell's *Annals*, 1792, p. 320.—mina, *Jour. de Phys.* xlix. 374.

Class I.
Order I.

weight. It tinges soda blue, but does not melt with it. When heated, acquires the electricity of the tourmaline.

According to the analysis of Mr Bindheim, it is composed of . . . . . .

57	silica
35	alumina
5	oxides of iron and manganese
97	

According to Lermina of

36	silica
48	alumina
3½	lime
9	oxide of manganese
96½	

Sp. 5. Hornslate *.

Shistose porphyry.

This stone, which occurs in mountains, is generally amorphous; but sometimes also in columns. Structure slaty. Texture foliated. Fracture uneven and splintery; sometimes approaching the conchoidal. Lustre 0. Transparency 1 or 0. Hardness about 10. Specific gravity from 2.512 to 2.7. Colour different shades of *grey*, from *ash* to *bluish* or *olive green*. Melts at 145° Wedgewood into an enamel. A specimen analysed by Wedgewood contained

73.0	silica
23.9	alumina
3.5	iron
100.4	

Sp. 6. Hornstone †.

Petrosilex—Chert.

This stone, which makes a part of many mountains,

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[*] Kirwan's *Min.* i. 307.—Wiegleb, Crell's *Annals*, 1787, 1 Band. 302. See also Reuss, *Samml. Natur. Hist. Aufsäze*, p. 207.

[†] Kirwan's *Min.* i. 303.—Baumer, *Jour. de Phys.* ii. 154. and Monnet, Ibid. 331.—Wiegleb, Crell's *Annals*, 1788, p. 45. and 135.—*Jour. de Phys.* lii. 239.

Genus VI.
2. SA.
Species VII.

is usually amorphous; but, as Mr Kirwan informs us, it has been found crystallized by Mr Beyer on Schneeberg. Its crystals are six-sided prisms, sometimes terminated by pyramids; hexahedrons, consisting of two three-sided pyramids applied base to base; and cubes, or six-sided plates *. Its texture is foliated. Fracture splintery, and sometimes conchoidal. Lustre 0. Transparency 1 to 2. The crystals are sometimes opaque. Hardness 7 to 9. Specific gravity 2.532 to 2.653. Colour usually dark blue: but hornstone occurs also of the following colours; grey, red, blue, green, and brown of different shades †.

Properties.

According to Kirwan, it is composed of

Composition.

72 silica
22 alumina
6 carbonat of lime

100 ‡

Sp. 7. Chalcedony.

This stone is found abundantly in many countries, particularly in Iceland and the Faro islands. It is most commonly amorphous, stalactitical, or in rounded masses; but it occurs also crystallized in six-sided prisms, terminated by pyramids, or more commonly in four or six-sided pyramids, whose sides are convex. Surface rough. Fracture more or less conchoidal. Lustre 1. Somewhat transparent. Hardness 10 to 11. Specific gravity 2.56 to 2.665. Not brittle.

According to Bergman, the chalcedony of Faro is composed of . . . . 84 silica
16 alumina, mixed with iron

100

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* Kirwan's *Min.* i. 303.

† Schmeisser's *Min.* i. 103.

‡ Ibid. p. 305.

Class I. Order I. Varieties.

Variety 1. Common chalcedony.—Fracture even, inclining to conchoidal. Transparency 2 to 3; sometimes 1. Its colours are various; it is most commonly greyish, with a tint of yellow, green, blue, or pearl; often also white, green, red, yellow, brown, black, or dotted with red. When striped white and black, or brown, alternately, it is called *onyx*; when striped white and grey, it is called *chalcedonix*. Black or brown chalcedony, when held between the eye and a strong light, appears dark red.

Variety 2. Cornelian.—Fracture conchoidal. Transparency 3 to 1; often cloudy. Its colours are various shades of red, brown, and yellow. Several colours often appear in the same mass. To this variety belong many of the stones known by the name of *Scotch pebbles*.

Sp. 8. Jasper *.

This stone is an ingredient in the composition of many mountains. It occurs usually in large amorphons masses, and sometimes also crystallized in six-sided irregular prisms. Its fracture is conchoidal. Lustre from 2 to 0. Either opaque, or its transparency is 1. Hardness 9 to 10. Specific gravity from 2.5 to 2.82. Its colours are various. When heated, it does not decrepitate. It seems to be composed of silica and alumina, and often also contains iron.

Varieties.

Variety 1. Common jasper.—Specific gravity from 2.58 to 2.7. Its colours are, different shades of white, yellow, red, brown, and green; often variegated, spotted, or veined, with several colours.

Variety 2. Egyptian pebble.—This variety is found

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* Kirwan's *Min.* i. 309.—Borral, *Hist. Natur. de Corse.*—Henkel, *Act. Acad. Nat. Curios.* v. 339.

Genus VI.
2. SA.
Species IX.

hiefly in Egypt. It usually has a spheroidal or flat ounded figure, and is enveloped in a coarse rough crust. t is opaque. Hardness 10. Specific gravity 2.564. t is chiefly distinguished by the variety of colours, hich always exist in the same specimen, either in conntric stripes or layers, or in dots or dendritical figures. hese colours are, different browns and yellows, milk hite, and isabella green; black also has been observed dots.

Variety 3. Striped jasper.—This variety is also ditinguished by concentric stripes or layers of different olours: these colours are, yellow, brownish red, and reen. It is distinguished from the last variety by its ccurring in large amorphous masses, and by its fracure, which is nearly even.

Sp. 9. Tripoli.

Properties.

This mineral is found sometimes in an earthy form, ut more generally indurated. Its texture is earthy. ts fracture often somewhat conchoidal. Lustre 0. Geerally opaque. Hardness 4 to 7. Specific gravity 2.080 o 2.529. Absorbs water. Feel, harsh dry. Hardly aderes to the tongue. Takes no polish from the nail. oes not stain the fingers. Colour generally pale yellowsh grey, also different kinds of yellow, brown, and white.

Composition.

It contains, according to Haasse, 90 parts of silica, alumina, and 3 of iron. A mineral belonging to this pecies was analysed by Klaproth, and found to contain

66.5	silica
7.0	alumina
2.5	oxide of iron
1.5	magnesia
1.25	lime
19.0	air and water
97.75	

Class I. Order I.

GENUS VII. 1. ASI.

Sp. 1. Micarell[*].

This name has been given by Mr Kirwan to a stone which former mineralogists considered as a variety of mica. It is found in granite. Its texture is foliated, and it may be split into thin plates. Lustre metallic, 3. Opaque. Hardness 6. Specific gravity, 2.980. Colour brownish black. At 153° Wedgewood, it melts into a black compact glass, the surface of which is reddish[†].

Composition.

A specimen analysed by Klaproth contained

63.00	alumina
29.50	silica
6.75	iron
99.25	

Sp. 2. Shorl[‡].

History.

No word has been used by mineralogists with less limitation than *shorl*. It was first introduced into mineralogy by Cronstedt, to denote any stone of a columnar form, considerable hardness, and a specific gravity from 3 to 3.4. This description applied to a very great number of stones; and succeeding mineralogists, though they made the word more definite in its signification, left it still so general, that under the designation of *shorl* almost 20 distinct species of minerals were included.

Mr Werner first defined the word *shorl* precisely, and restricted it to one species of stones. I use the word in the sense assigned by him.

Shorl is found abundantly in mountains, either massive, or crystallized in three or nine sided prisms, often

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[*] Kirwan's *Min.* i. 212. [†] Kirwan, Ibid. [‡] Ibid. i. 265.

Genus VII.
I. ASI.
Species III.

Properties.

terminated by three-sided summits. The sides of the crystals are longitudinally streaked. Its texture is foliated. Its fracture conchoidal. Lustre 2. Opaque. Hardness 10. Specific gravity 2.92 to 3.212. Colour black. Streak grey. It does not become electric by heat. When heated to redness, its colour becomes brownish red; and at 127° Wedgewood, it is converted into a brownish compact enamel *. According to Wiegleb, it is composed of

Composition.

41.25 alumina
34.16 silica
20.00 iron
5.41 manganese

100.82 †

Sp. 3. Granatite.

Staurotide of Hauy—*Pierre de Croix* of De Lisle—*Staurolithe* of Lametherie.

I have adopted from Mr Vauquelin the term *granatite* to denote this stone, because all the other names are ambiguous, having been applied to another mineral possessed of very different properties.

Crystals.

Granatite is found in Galicia in Spain, and Britanny in France. It is always crystallized in a very peculiar form; two six-sided prisms intersect each other, either at right angles or obliquely. Hence the name *cross-stone*, by which it was known in France and Spain ‡. Mr Hauy has proved, in a very ingenious manner, that the primitive form of the granatite is a rectangular prism, whose bases are rhombs, with angles of 129½° and 50½°; and that the height of the prism is to the

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* Kirwan's *Min.* i. 166.

† Crell's Beitrage, 1. Band. 4 Stuck,. p. 21.

‡ Romé de Lisle, ii. 435.

greater diagonal of a rhomb as 1 to 6; and that its integrant molecules are triangular prisms, similar to what would be obtained by cutting the primitive crystal in two, by a plane passing vertically through the shorter diagonal of the rhomboidal base. From this structure he has demonstrated the law of the formation of the cruciform varieties[*]. The colour of granatite is greyish or reddish brown. Specific gravity 3.2861. Hardness 12. Texture compact. Usually opaque,

Composition. According to the analysis of Vauquelin, it is composed of

47.06 alumina
30 59 silica
15.30 oxide of iron
3.00 lime

95.95[†]

GENUS VII. 2. SAI.

Sp. 4. Tourmaline[‡].

This stone was first made known in Europe by specimens brought from Ceylon; but it is now found frequently forming a part of the composition of mountains.

Crystals. It is either in amorphous pieces, or crystallized in three or nine sided prisms, with four-sided summits. The primitive form of its crystals is an obtuse rhomboid; that of its integrant particles an irregular tetrahedron.

Properties. Its texture is foliated: Its fracture conchoidal. Internal lustre 2 to 3. Transparency 3 to 4; sometimes

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[*] *Ann. de Chim.* vi. 142.

[†] Ibid. xxx. 106.

[‡] Kirwan, i. 271.—Bergman, ii. 118. and v. 402.—Gerhard, *Mem. Berl.* 1777, p. 14.—Hauy, *Mem. Par.* 1784, p. 270.—Wilson, *Phil. Trans.* xli. 308.—Æpinus, *Recueil sur la Tourmaline.*—See also La Porterie, *le Saphir, l'Oeil de Chat, et la Tourmaline de Ceylon demasqués.*

only 2*. Causes only single refraction†. Hardness 9 to 11. Specific gravity 3.05 to 3.155. Colour brown, often so dark that the stone appears black; the brown has also sometimes a tint of green, blue, red, or yellow.

When heated to 200° Fahrenheit, it becomes electric; one of the summits of the crystal negatively, the other positively‡. It reddens when heated; and is fusible *per se* with intumescence into a white or grey enamel.

Composition.

A specimen of the tourmaline of Ceylon, analysed by Vauquelin, was composed of

40	silica
39	alumina
12	oxide of iron
4	lime
2.5	oxide of manganese
97.5 §	

Sp. 5. Argentine felspar ||.

This stone was discovered by Mr Dodun in the black mountains of Languedoc. It is either amorphous, or crystallized in rhomboidal tables, or six or eight sided prisms. Its texture is foliated. Fragments rectangular. Laminæ inflexible. Internal lustre 4. Transparency 2. Colour white; two opposite faces of the crystals are silver white, two others dead white. Hardness of the silver laminæ 6, of the rest 9. Brittle. Specific gravity 2.5. When the flame of the blow-pipe

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* And when black only 1. It is always opaque when viewed in a direction parallel to the axis of the crystal.

† Hauy, *Jour. de Min.* No. xxviii. 265.

‡ Æpinus.

§ *Ann. de Chim.* xxx. 105.

|| Kirwan, i. 327.

Class I. Order I.

is directed against the edges of the crystal (stuck upon glass), it easily melts into a clear compact glass; but when the flame is directed against the faces, they preserve their lustre, and the edges alone slowly melt.

According to the analysis of Dodun, it is composed of

46	silica
36	alumina
16	oxide of iron
98	

When this stone is exposed to the atmosphere, it is apt to decay: Its surface becomes iridescent, and at last changes to ochre-yellow: Its specific gravity is 2.3 or 2.212; and when breathed upon, it gives out an earthy smell.

Sp. 6. Mica*.

This stone forms an essential part of many mountains, and has been long known under the names of *glacies mariæ* and *Muscovy glass.* It consists of a great number of thin laminæ adhering to each other, sometimes of a very large size. Specimens have been found in Siberia nearly 2½ yards square †.

Crystals.

It is sometimes crystallized: Its primitive form is a rectangular prism, whose bases are rhombs, with angles of 120° and 60°: Its integrant molecule has the same form. Sometimes it occurs in rectangular prisms, whose bases also are rectangles, and sometimes also in short six-sided prisms; but it is much more frequently in plates or scales of no determinate figure or size ‡.

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* Kirwan, i. 210.—Gmelin, *Nov. Com. Petropol.* xii. 549.

† *Hist. General de Voyages*, t. xviii. 272. quoted by Hauy, *Jour. de Min.* No. xxviii. 299.

‡ Hauy, *Jour. de Min.* No. xxviii. 296.

Genus VII. 2 Sal. Species VII.

Properties.

Its texture is foliated. Its fragments flat. The lamellæ flexible, and somewhat elastic. Lustre metallic, from 3 to 4. Transparency of the laminæ 3 or 4, sometimes only 2[*]. Hardness 6. Very tough. Often absorbs water. Specific gravity from 2.6546 to 2.9342. Feels smooth, but not greasy. Powder feels greasy. Colour, when purest, silver white or grey; but it occurs also yellow, greenish, reddish, brown, and black. Mica is fusible by the blow-pipe into a white, grey, green, or black enamel; and this last is attracted by the magnet[†]. Spanish wax rubbed by it becomes negatively electric[‡].

Composition.

A specimen of mica, analysed by Vauquelin, contained

50.00	silica
35.00	alumina
7.00	oxide of iron
1.35	magnesia
1.33	lime
94.68[§]	

Mica has long been employed as a substitute for glass. A great quantity of it is said to be used in the Russian marine for panes to the cabin windows of ships; it is preferred, because it is not so liable as glass to be broken by the agitation of the ship.

Sp. 7. Talc[¶].

This stone has a very strong resemblance to mica,

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[*] Black mica is often nearly opaque.

[†] Hauy, *Jour. de Min.* No. xxviii. p. 295. Bergman, however, found pure mica infusible *per se*.

[‡] Ibid.

[§] Ibid.

[¶] Kirwan, i. 150.—*Pott. Mem. Berl.* 1746, p. 65.

Class I. Order I.

and was long considered as a mere variety of that mineral. It occurs sometimes in small loose scales, and sometimes in an indurated form; but it has not hitherto been found crystallized.

Properties.

Its texture is foliated. The lamellæ are flexible, but not elastic. Its lustre is from 2 to 4. Transparency from 2 to 4. Hardness 4 to 6. Specific gravity, when indurated, from 2.7 to 2.8. Feels greasy. Colour most commonly whitish or greenish. Spanish wax rubbed with it becomes *positively* electric *.

Varieties.

Variety 1. Scaly talc. *Talcite* of Kirwan.—This variety occurs under the form of small scales, scarcely cohering. Lustre 3 to 4. Very light. Adheres to the fingers. When rubbed upon the skin, it gives it a gloss. Colour white, with a shade of red or green; sometimes leek green.

Variety 2. Common talc. *Venetian talc.*—This variety often occurs in oblong nodules. Lustre, nearly metallic, 4. Transparency 2 to 3; when very thin 4. Hardness 4 to 5. Colour white, with a shade of green or red; or apple green, verging towards silver white. By transmitted light green.

Variety 3. Shistose talc.—Its structure is slaty. Fracture hackly and long splintery. Easily crumbles when rubbed in the fracture. External lustre, 2 to 3; internal, 1; but sometimes, in certain positions, 3. Colour grey, with a shade of white, green, or blue. Becomes white and scaly when exposed to the air.

A specimen of *common talc*, analysed by Mr Chenevix, contained

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* Hauy, *Jour de Min.* No. xxviii. 291.

Genus VII.
2. SAI.
Sp. VIII.

48.0 silica
37.0 alumina
6.0 oxide of iron
1.5 magnesia
1.5 lime
5.0 water

99.0[*]

Sp. 8. Basaltine[†].

Basaltic hornblende of Werner—*Actinote* of Hauy—
Zillertite of Lametherie.

Properties.

This stone is found commonly in basaltic rocks;
nce its name, which was imposed by Mr Kir-
an. It is crystallized, either in rhomboidal prisms,
six or eight-sided prisms, terminated by three-sided
ramids. The primitive form of its crystals is a rhom-
idal prism. Its texture is foliated. Its fracture un-
en. Lustre 3. Transparency, when in very thin
ates, 1. Hardness from 9 to 10. Specific gravity
333. Colour black, dark green, or yellowish green.
reak white. Transmits a reddish yellow light. Be-
e the blow-pipe it melts into a greyish coloured en-
nel, with a tint of yellow[‡]. A specimen, seemingly
this stone, analysed by Bergman, contained

Composition.

58 silica
27 alumina
9 iron
4 lime
1 magnesia

99[§]

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[*] *Ann. de Chim.* xxviii. 200.

[†] Kirwan, i. 219.

[‡] Le Lievre, *Jour. de Min.* No. xxviii. 269.

[§] Bergman, iii. 207.

Sp. 9. Hornblende*.

Amphibole of Hauy†.

This stone enters into the composition of various mountains. Its texture is very conspicuously foliated. Fracture conchoidal. Fragments often rhomboidal. Lustre 2. Opaque. Hardness 5 to 9. Tough. Specific gravity 2.922 to 3.41. Colour black, blackish green, olive green, or leek green. Streak greenish. It neither becomes electric by friction nor heat ‡. Before the blow-pipe it melts into a black glass. A specimen of black hornblende, analysed by Mr Hermann,

Composition.

was composed of

37	silica
27	alumina
25	iron
5	lime
3	magnesia
97§	

Sp. 10. Resplendent Hornblende.

There are two minerals which Werner considers as varieties of hornblende, and Mr Kirwan as constituting a distinct species. These, till future analyses decide the point, I shall place here under the name of resplendent hornblende, the name given them by Mr Kirwan; and I shall describe them separately.

Varieties.

Variety 1. Labradore hornblende.—Texture curved foliated. Lustre, in some positions, 0; in others metallic, and from 3 to 4. Opaque. Hardness 8 to 9.

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* Kirwan, i. 213.

† Under this name Mr Hauy comprehends *shorl* also.

‡ Hauy, *Jour. de Min.* No. xxviii. 267.

§ *Beob. der Berlin*, 5 Band. 317.

Genus VII.
2. SAL.
Species XI.

Specific gravity from 3.35 to 3.434. Colour, in most positions, greyish black; in others, it reflects a strong iron grey, sometimes mixed with copper red.

Variety 2. Shiller spar *.—Texture foliated. Lustre metallic, 4. Transparency, in thin pieces, 1. Hardness 8 to 9. Specific gravity 2.882. Colour green, often with a shade of yellow; also golden yellow. In some positions it reflects white, grey, or yellow. At 141° Wedgewood, hardened into a porcelain mass. A specimen, analysed by Gmelin, was composed of

43.7 silica
17.9 alumina
23.7 iron
11.2 magnesia

96.5†

It has been found in the Hartz, stuck in a serpentine rock.

Sp. 11. Obsidian ‡.

Iceland agate.

This stone is found either in detached masses, or forming a part of the rocks which compose many mountains. It is usually invested with a grey or opaque crust. Its fracture is conchoidal. Its internal lustre 3. Transparency 1. Hardness 10. Specific gravity 2.348. Colour black or greyish black: when in very thin pieces, green. It melts into an opaque grey mass. According to Bergman, it is composed of 69 silica

22 alumina
9 iron

100§

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[*] Kirwan, i. 221.

[†] Bergbaukunde, 1 Band. p. 92.

[‡] Kirwan, i. 264.

[§] Bergman, iii. 204.

Class I.
Order I.

Sp. 12. Petrilite *.

Cubic felspar.

This stone is found in the mass of mountains. It is amorphous. Texture foliated. Fracture splintery. Fragments cubic, or inclining to that form; their faces unpolished. Lustre 2. Transparency partly 2, partly 1. Hardness 9. Specific gravity, 3.081. Colour reddish brown. Does not melt at 160° Wedgewood.

Sp. 13. Felsite †.

Compact felspar.

This stone also forms a part of many mountains, and is amorphous. Texture somewhat foliated. Fracture uneven, approaching to the splintery. Lustre 1. Transparency scarce 1. Hardness 9. Colour azure blue, and sometimes brown and green. Streak white. Before the blow-pipe whitens and becomes rifty; but is infusible *per se*.

GENUS VIII. SNAW.

Sp. 1. Pimelite.

The mineral distinguished by this name is an earthy substance, of an apple green colour, which accompanies the chrysopase of Tkosemütz. Klaproth has analysed it, and found it composed of the following ingredients.

35.00	silica
15.62	oxide of nickel
5.00	alumina
4.58	oxide of iron
1.25	magnesia
37.91	water
99.36‡	

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* Kirwan, i. 325.

† Ibid. 326.

‡ *Jour. de Phys.* lii. 39.

Genus IX.
Sap.
Species I.

Genus IX. Sap.

Sp. 1. Felspar[*].

Crystals.

This stone forms the principal part of many of the highest mountains. It is commonly crystallized. Its primitive form, according to De Lisle, is a rectangular prism, whose bases are rhombs, with angles of 65° and 115°. Sometimes the edges of the prism are wanting, and faces in their place; and sometimes this is the case also with the acute angles of the rhomb. For a description and figure of these, and other varieties, the reader is referred to *Romé de Lisle* [†], *Mr Hauy* [‡], and *Mr Pini* [§].

Properties.

Its texture is foliated. Its cross fracture uneven. Fragments rhomboidal, and commonly smooth and polished on four sides. Lustre of the polished faces often 3. Transparency from 3 to 1. Hardness 9 to 10. Specific gravity from 2.437 to 2.7. Gives a peculiar odour when rubbed. It is made electric with great difficulty by friction. Fusible *per se* into a more or less transparent glass. When crystallized, it decrepitates before the blow-pipe.

Varieties.

Variety 1. Pure felspar. *Moonstone—Adularia.*— This is the purest felspar hitherto found. It occurs in Ceylon and Switzerland; and was first mentioned by Mr Sage. Lustre nearly 3. Transparency 2 to 3. Hardness 10. Specific gravity 2.559. Colour white; sometimes with a shade of yellow, green, or red. Its surface is sometimes iridescent.

Variety 2. Common felspar. Lustre of the cross

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[*] Kirwan, i. 316. and *Jour. de Phys.* passim.

[†] *Crystall.* ii. 461. [‡] *Mem. Par.* 1784, p. 273.

[§] *Sur de Nouvelle Crystallisation*, &c. 8.

Class I. Order I.

fracture 0; of the fracture, in the direction of the laminæ, from 3 to 1. Transparency 2 to 1. Colour most commonly flesh red; but often bluish grey, yellowish white, milk white, brownish yellow; and sometimes blue, olive green, and even black.

Variety 3. Labradore felspar.—This variety was discovered on the coast of Labradore by Mr Wolfe; and since that time it has been found in Europe. Lustre 2 to 3. Transparency from 1 to 3. Specific gravity from 2.67 to 2.6925. Colour grey. In certain positions, spots of it reflect a blue, purple, red, or green colour.

Variety 4. Continuous felspar.—This variety most probably belongs to a different species; but as it has not hitherto been analysed, I did not think myself at liberty to alter its place.

It is found in large masses. Texture earthy. Fracture uneven, sometimes splintery. Lustre 0. Transparency 1. Hardness 10. Specific gravity 2.609. Colour reddish grey, reddish yellow, flesh red.

Composition.

A specimen of green felspar from Siberia, analysed by Vauquelin, contained

62.83	silica,
17.02	alumina,
16.00	potass,
3.00	lime,
1.00	oxide of iron.
99.85 *	

Sp. 2. Lepidolite †.

Lilalite.

This stone appears to have been first observed by the

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* *Ann. de Chim.* xxx. 106.

† Kirwan, i. 208.—Karsten, *Beob, der Berlin,* 5 Band. 71.—Klaproth's Beitrage, i. 279. and ii. 191.

Abbé Poda, and to have been first described by De Born [*]. Hitherto it has only been found in Moravia in Germany, and Sudermania in Sweden [†]. There it is mixed with granite in large amorphous masses. It is composed of thin plates, easily separated, and not unlike those of mica [‡]. Lustre, pearly 3. Transparency between 1 and 2. Hardness 4 to 5. Not easily pulverised [§]. Specific gravity from 2.816 [‖] to 2.8549 [¶]. Colour of the mass, violet blue; of the thin plates, silvery white. Powder white, with a tint of red [**]. Before the blow-pipe, it froths, and melts easily into a white semitransparent enamel, full of bubbles. Dissolves in borax with effervescence, and communicates no colour to it [††]. Effervesces slightly with soda, and melts into a mass spotted with red. With microcosmic salt, it gives a pearl-coloured globule [‡‡].

Properties.

This stone was first called lilalite from its colour, that of the *lily*. Klaproth, who discovered its component parts, gave it the name of *lepidolite* [§§].

Composition.

It is composed of

53	silica,
20	alumina,
18	potass,
5	fluat of lime,
3	oxide of manganese,
1	oxide of iron.
100 [‖‖]	

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[*] Crell's *Annals*, 1791, ii. 196.

[†] Beyer, *Ann. de Chim.* xxix. 108.

[‡] Le Lievre, *Jour. de Min.* No. li. 219.

[§] Ibid.

[‖] Klaproth.

[¶] Hauy.

[**] Le Lievre, *Jour. de Min.* No. li. 219.

[††] Ibid.

[‡‡] Klaproth, *Ann. de Chim.* xxii. 37.

[§§] That is, *scale stone*, or stone composed of scales: From λεπις, *the scale of a fish*, and λιθος, a *stone*.

[‖‖] Vauquelin, *Ann. de Chim.* xxx. 105.

Class I.
Order I.

Sp. 3. Leucite[*].

Vesuvian of Kirwan—*White garnet of* Vesuvius.

This stone is usually found in volcanic productions, and is very abundant in the neighbourhood of Vesuvius.

Crystals.

It is always crystallized. The primitive form of its crystals is either a cube or a rhomboidal dodecahedron, and its integrant molecules are tetrahedrons; but the varieties hitherto observed are all polyhedrons. The most common has a spheriodal figure, and is bounded by 24 equal and similar trapezoids; sometimes the faces are 12, 18, 36, 54, and triangular, pentagonal, &c. For a description and figure of several of these, I refer the reader to Mr Hauy[†]. The crystals vary from the size of a pin head to that of an inch.

Properties.

The texture of the leucite is foliated. Its fracture somewhat conchoidal. Lustre 3; when in a state of decomposition 0. Transparency 3 to 2; when decomposing 0. Hardness 8 to 10; when decomposing 5 to 6. Specific gravity 2.4648. Colour white, or greyish white[‡]. Its powder causes syrup of violets to assume a green colour[§].

Composition.

It is composed, as Klaproth has shewn, of

54 silica
23 alumina
22 potass

99[||]

It was by analysing this stone that Klaproth disco-

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[*] Kirwan, i. 285.

[†] *Jour. de Min.* No. xxvii. 185.

[‡] Hence the name leucite, from λευκος, *white.*

[§] Vauquelin, *Jour. de Min.* No. xxxix. 165.

[||] See *Jour. de Min.* No. xxvii. 194. and 201. and Klaproth's Beitrage, ii. 39.

ered the presence of potass in the mineral kingdom; hich is not the least important of the numerous discoeries of that accurate and illustrious chemist.

Leucite is found sometimes in rocks which have never een exposed to volcanic fire; and Mr Dolomieu has endered it probable, from the substances in which it is ound, that the leucite of volcanoes has not been formed y volcanic fire, but that it existed previously in the ocks upon which the volcanoes have acted, and that was thrown out unaltered in fragments of these ocks *.

Sp. 4. White Chlorite.

This is a mineral composed of brilliant scales of a lvery white colour, very soft, and when rubbed upon ther bodies, leaving a powder resembling the scales of sh. Smell argillaceous. Water in which it is agitated ecomes alkaline. Before the blow-pipe, melts into a reenish white enamel. When calcined, loses 0.06 of s weight, and becomes reddish. It is composed of

56	silica
18	alumina
8	potass
3	lime
4	oxides of iron and manganese
6	water
95 †	

GENUS X. SAG.

Sp. 1. Emerald ‡.

This stone has hitherto been only found crystallized.

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* *Jour. de Min.* No. xxxix. 177. † Vauquelin, *Jour. de Phys.* lii. 245.

Kirwan, i. 247. and 248.—Dolomieu, *Magazin Encyclopædique*, ii. 17. l 145.; and *Jour. de Min.* No. xviii. 19.—Klaproth's Beitrage, ii. 12.

Class I. Order I.

Crystals.

The primitive form of its crystals is a regular six-sided prism; and the form of its integrant molecules is a triangular prism, whose sides are squares, and bases equilateral triangles *. The most common variety of its crystals is the regular six-sided prism, sometimes with the edges of the prism, or of the bases, or the solid angles, or both wanting, and small faces in their place †. The sides of the prism are generally channelled.

Properties.

Its texture is foliated. Its fracture conchoidal. Lustre usually from 3 to 4. Transparency from 2 to 4. Causes a double rafraction. Hardness 12. Specific gravity 2.65 to 2.775. Colour green. Becomes electric by friction, but not by heat. Its powder does not phosphoresce when thrown on a hot iron ‡. At 150° Wedgewood it melts into an opaque coloured mass. According to Dolomieu, it is fusible *per se* by the blowpipe §.

This mineral was formerly subdivided into two distinct species, the *emerald*, and *beryl* or *aqua marina*. Hauy demonstrated, that the emerald and beryl corresponded exactly in their structure and properties; and Vauquelin found that they were composed of the same ingredients: henceforth, therefore, they must be considered as varieties of the same species.

Emerald.

The variety formerly called *emerald* varies in colour from the pale to the perfect green. It comes chiefly from Peru; some specimens have been brought from Egypt. Dolomieu found it in the granite of Elba. When heated to 120° Wedgewood, it becomes *blue*,

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* Hauy, *Jour. de Min.* No. xix. 72.

† Romé de Lisle, ii. 445. and Hauy, ibid.

‡ Dolomieu, *Jour. de Min.* No. xviii. 19.

§ Ibid.

Genus X.
SAG.
Species II.

t recovers its colour when cold. A specimen, ana-sed by Vauquelin, was composed of

64,60	silica,
14.00	alumina,
13.00	glucina,
3.50	oxide of chromum,
2.56	lime,
2.00	moisture or other volatile ingredient.
99.66 *	

Beryl.

The *beryl* is of a greyish green colour, and sometimes ue, yellow, and even white: somtimes different co-urs appear in the same stone †. It is found in Ceylon, fferent parts of India, Brazil, and especially in Siberia d Tartary, where its crystals are sometimes a foot ng ‡. A specimen of beryl, analysed by Vauquelin, ntained

69	silica,
13	alumina,
16	glucina,
1.5	
99.5 §	

It was by analysing this stone that Vauquelin disco-red the earth which he called *glucina.*

Sp. 2. Euclase.

This stone, which has lately been brought from Peru r Dombey, was at first confounded with the emerald n account of its green colour. The primitive form of s crystals is a rectangular prism, whose bases are quares. It is very brittle; sufficiently hard to scratch

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* *Ann. de Chim.* xxvi. 264.

† Dolomieu, ibid.

‡ Ibid.

§ *Ann. de Chim.* xxxviii. 168.

Class I.
Order I.

quartz. Transparency considerable. Causes double refraction. Specific gravity 3.0625. Fusible by the blow-pipe into a white enamel. A small specimen, analysed by Vauquelin, yielded the following ingredients . . . . 36 silica
23 alumina
15 glucina
5 oxide of iron

79*

The loss, which amounts to 21, was probably owing to the presence of an alkali, which the smallness of the specimen analysed did not permit Vauquelin to ascertain.

GENUS XI. SAB.

Sp. 1. Staurolite†.

Andreolite of Lametherie and Hauy—*Hyacinthe blanche cruciforme*, var. 9. of Romé de Lisle.

This stone has been found at Andreasberg in the Hartz. It is crystallized, and the form of its crystals has induced mineralogists to give it the name of *cross-stone*. Its crystals are two four-sided flattened prisms, terminated by four-sided pyramids, intersecting each other at right angles; the plane of intersection passing longitudinally through the prisms‡.

Properties.

Its texture is foliated. Its lustre waxy, 2. Transparency from 1 to 3. Hardness 9. Brittle. Specific gravity 2.355 to 2.361. Colour milk white. When heated slowly, it loses 0.15 or 0.16 parts of its weight, and falls into powder. It effervesces with borax and

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* *Jour. de Phys.* lii. 317.

† Kirwan, i. 282.

‡ See also Gillot, *Jour. de Phys.* 1793, p. 1. and 2.

Genus XII
I. ASL.
Species I.

icrocosmic salt, and is reduced to a greenish opaque ass. With soda it melts into a frothy white enamel. Vhen its powder is thrown on a hot coal, it emits a reenish yellow light*.

Composition.

A specimen analysed by Westrum was composed of

44 silica
20 alumina
20 barytes
16 water

100

Klaproth found the same ingredients, and nearly in e same proportions†.

Variety.

A variety of staurolite has been found only once; hich has the following properties.

Its lustre is pearly, 2. Specific gravity 2,361. Coour brownish grey. With soda it melts into a purplish nd yellowish frothy enamel. It is composed, according Westrum, of

47.5 silica
12.0 alumina
20.0 barytes
16.0 water
4.5 oxides of iron and manganese

100.0

GENUS XII. I. ASL.

Sp. I. Chrysoberyl‡.

riental chrysolite of jewellers—*Cymophane* of Hauy—
Chrysopal of Delametherie.

Hitherto this stone has been found only in Brazil, the

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[*] Hauy, *Jour. de Min.* No. xxviii. 280.

[†] Beitrage, ii. 80.

[‡] Kirwan, i. 261.

Class I. Order I.

island of Ceylon, and as some affirm near Nortschink in Siberia. Werner first made it a distinct species, and gave it the name which it now bears. It is usually found in round masses about the size of a pea, but it is

Crystals.

sometimes also crystallized. The primitive form of its crystals is a four-sided rectangular prism, whose height is to its breadth as $\sqrt{3}$ to 1, and to its thickness as $\sqrt{2}$ to 1. The only variety hitherto observed is an eight-sided prism, terminated by six-sided summits. Two of the faces of the prism are hexagons, two are rectangles, and four trapeziums; two faces of the summits are rectangles, and the other four trapeziums. Sometimes two of the edges of the prism are wanting, and small faces in their place*.

Properties.

Its texture is foliated. Laminæ parallel to the faces of the prism. Lustre 3 to 4. Transparency 3 to 4. Causes single refraction. Hardness 12. Specific gravity from 3.698 † to 3.7961 ‡. Colour yellowish green, surface sparkling. It is infusible by the blow-pipe *per se*, and with soda.

A specimen of chrysoberyl, analysed by Klaproth, was composed of

71.5	alumina
18.0	silica
6.0	lime
1.5	oxide of iron
97.0 §	

GENUS XIII. 2. SAL.

Sp. 2. Hyalite ||.

This stone is found frequently in trap. It occurs in grains, filaments, and rhomboidal masses. Texture fo-

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[*] Hauy. *Jour. de Min.* No. xxi. 5.

[†] Werner.

[‡] Hauy

[§] Beitrage, i. 102.

[||] Kirwan, i. 296.

Genus XII.
2. SAL.
Species III.

liated. Fracture uneven, inclining to conchoidal. Lustre glassy[*], 2 to 3. Transparency 2 to 3; sometimes, tho' seldom, it is opaque. Hardness 9. Specific gravity 2.11[†]. Colour pure white. Infusible at 150° Wedgewood; but it yields to soda[‡]. According to Mr Link, it is composed of 57 silica
18 alumina
15 lime

90 and a very little iron[§]

Sp. 3. Ædelite[||].

This stone has hitherto been found only in Sweden at Mosseberg and Ædelfors. From this last place Mr Kirwan, who first made it a distinct species, has given it the name of ædelite. It was first mentioned by Bergman[¶]. Its form is tuberose and knotty. Texture striated; sometimes resembles quartz. Lustre from 0 to 1. Specific gravity 2.515 after it has absorbed water[**]. Colour light grey, often tinged red; also yellowish brown, yellowish green and green. Before the blow-pipe it intumesces and forms a frothy mass. Acids convert it into a jelly[††]. A specimen from Mosseberg, analysed by Bergman, contained

69 silica
20 alumina
8 lime
3 water

100[‡‡]

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[*] Hence probably the name *hyalite*, which was imposed by Werner from *ὑαλις glass*, and *λιθος a stone*.

[†] Kirwan.

[‡] Id.

[§] Crell's *Annals*, 1790, 2 Band. 232.

[||] Kirwan, i. 276.

[¶] *Opusc.* vi. 101.

[**] Kirwan, i. 276.

[††] Bergman, iii. 227.

[‡‡] *Opusc.* vi. 101.

Class I.
Order I.

A specimen from Ædelfors yielded to the same chemist . . . . 62 silica
18 alumina
16 lime
4 water

100*

Sp. 4. Scapolite.

This mineral has been found at Arendal in Norway. It is of a pearl white colour, and is crystallized in long rectangular prisms. Its specific gravity is 3.680, and it is hard enough to scratch glass.

According to Abelgaard, it is composed of
38 silica
30 alumina
14 lime
1 oxide of iron
2 water

95†

GENUS. XII. 3. SAWL.

Sp. 5. Zeolite‡.

This stone was first described by Cronstedt in the Stockholm Transactions for 1756. It is found sometimes amorphous and sometimes crystallized. The primitive form of its crystals is a rectangular prism, whose bases are squares. The most common variety is a long four-sided prism, terminated by low four-sided pyramids §.

Crystals.

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[*] *Opusc.* vi. 101.

[†] *Jour. de Phys.* lii. 33.

[‡] Kirwan, i. 278.—Guettard, iv. 637.—Bucquet, *Mem. Sav. Etrang.* ix. 576.—Pelletier, *Jour. de Phys.* xx. 420.

[§] Hauy, *Jour. de Min.* No. xiv. 86.

Genus XII.
3. SAWL.
Species VI.

Properties.

Its texture is striated or fibrous. Its lustre is silky, rom 3 to 1. Transparency from 2 to 4; sometimes . Hardness 6 to 8; sometimes only 4. Absorbs ater. Specific gravity 2.07 to 2.3. Colour white, ften with a shade of red or yellow; sometimes brick ed, green, blue. When heated, it becomes electric like he tourmaline *. Before the blow-pipe it froths †, enits a phosphorescent light, and melts into a white senitransparent enamel, too soft to cut glass, and soluble n acids. In acids it dissolves slowly and partially withut effervescence; and at last, unless the quantity of liuid be too great, it is converted into a jelly.

Composition.

A specimen of zeolite ‡, analysed by Vauquelin, conained . . . . 53.00 silica
27.00 alumina
9.46 lime
10.00 water

99.46 §

Sp. 6. Stilbite.

This stone was first formed into a distinct species by Ir Hauy. Formerly it was considered as a variety of eolite.

Crystals.

The primitive form of its crystals is a rectangular rism, whose bases are rectangles. It crystallizes somemes in dodecahedrons, consisting of a four-sided prism

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* Hauy, *Jour. de Min.* No. xxviii. 276.

† Hence the name *zeolite*, given to this mineral by Cronstedt; from ω *to ferment*, and λιθος *a stone*.

‡ Dr Black was accustomed to mention, in the course of his lectures, at Dr Hutton had discovered *soda* in zeolite. This discovery has not itherto been verified by any other chemical mineralogist.

§ *Jour. de Min.* No. xliv. 576.

Class I. Order I.

with hexagonal faces, terminated by four-sided summits, whose faces are oblique parallelograms; sometimes in six-sided prisms, two of whose solid angles are wanting, and a small triangular face in their place *.

Properties.

Its texture is foliated. The laminæ are easily separated from each other, and are somewhat flexible. Lustre pearly, 2 or 3 †. Hardness inferior to that of zeolite, which scratches stilbite. Brittle. Specific gravity 2.500‡. Colour pearl white. Powder bright white, sometimes with a shade of red. This powder, when exposed to the air, cakes and adheres as if it had absorbed water. It causes syrup of violets to assume a green colour. When stilbite is heated in a porcelain crucible, it swells up and assumes the colour and semitransparency of baked porcelain. By this process it loses 0.185 of its weight. Before the blow-pipe it froths like borax, and then melts into an opaque white coloured enamel §.

According to the analysis of Vauquelin, it is composed of . . . . . .

Composition.

52.0	silica
17.5	alumina
9.0	lime
18.5	water
97.0¶	

Sp. 7. Chabasie.

This mineral, which was first separated from the succeeding species by Bosc d'Antic and Hauy, is found at

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* Hauy, *Jour de Min.* No. xiv. 86.

† Hence the name given to this mineral by Hauy, *stilbite*, from στιλβω *to shine.*

‡ Hauy, Ibid. No. xxviii. 276.

§ Vauquelin, Ibid. No. xxxix. 161.

¶ Ibid. 164.

Genus XII. 4. SLA. Species IX.

berstein in Germany. It has a white colour, and laminated texture. The primitive form of its crystals is rhomboid slightly obtuse. Specific gravity 2.1176. carcely scratches glass.

Sp. 8. Analcime.

This stone, which was discovered by Mr Dolomieu, s found crystallized in the cavities of lava. It was first made a distinct species by Mr Hauy. Mineralogists ad formerly confounded it with zeolite.

Crystals.

The primitive form of its crystals is a cube. It is ometimes found crystallized in cubes, whose solid angles are wanting, and three small triangular faces in place of each; sometimes in polyhedrons with 24 faces. It is usually somewhat transparent. Hardness about ; scratches glass slightly. Specific gravity above 2. When rubbed, it acquires only a small degree of electricity, and with difficulty *. Before the blow-pipe it melts without frothing into a white semitransparent glass †.

GENUS XII. 4. SLA.

Sp. 9. Lazulite ‡.

This stone, which is found chiefly in the northern parts of Asia, has been long known to mineralogists by the name of *lapis lazuli*. This term has been contracted into *lazulite* by Mr Hauy; an alteration which was ertainly proper, and which therefore I have adopted.

Properties.

Lazulite is always amorphous. Its texture is earthy. Its fracture uneven. Lustre 0. Opaque, or nearly so. Hardness 8 to 9. Specific gravity 2.76 to 2.945 §. Co-

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* Hence the name *analcime* given it by Hauy, from αναλκις *weak*.

† Hauy, *Jour. de Min.* No. xiv. 86. and xxviii. 278.

‡ Kirwan, i. 283.

§ Brisson.

lour blue * ; often spotted white from specks of quartz, and yellow from particles of pyrites.

It retains its colour at 100° Wedgewood; in a higher heat it intumesces, and melts into a yellowish black mass. With acids it effervesces a little, and if previously calcined, forms with them a jelly.

Margraff published an analysis of lazulite in the Berlin Memoirs for 1758. His analysis has since been confirmed by Klaproth, who found a specimen of it to

Composition.

contain . . . . 46.0 silica
14.5 alumina
28.0 carbonat of lime
6.5 sulphat of lime
3.0 oxide of iron
2.0 water

100.0†

From the experiments of Morveau, it appears that the colouring matter of lazulite is sulphuret of iron.

GENUS XIII. SALI.

Sp. 1. Garnet‡.

This stone is found abundantly in many mountains.

Crystals.

It is usually crystallized. The primitive form of its crystals is a dodecahedron whose sides are rhombs, with angles of 78° 31′ 44″, and 120° 28′ 16″. The inclination of the rhombs to each other is 120°. This dode-

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[*] Hence the name *lazulite*, from an Arabian word *azul*, which signifies *blue*.

[†] Beitrage, i. 196.

[‡] Kirwan, i. 258.—Gerhard, *Disquisitio Physico-chymica Granatorum*, &c.—Pasumot, *Jour. de Phys.* iii. 442.—Wiegleb, *Ann. de Chim.* i 231.

Genus XIII.
SALI.
Species I.

cahedron may be considered as a four-sided prism, terminated by four-sided pyramids *. It is divisible into four parallelopipeds, whose sides are rhombs; and each of these may be divided into four tetrahedrons, whose sides are isosceles triangles, equal and similar to either of the halves into which the rhomboidal faces of the dodecahedron are divided by their shorter diagonal. The integrant molecules of garnet are similar tetrahedrons †. Sometimes the edges of the dodecahedron are wanting, and small faces in their place; and sometimes garnet is crystallized in polyhedrons, having 24 trapezoidal faces. For a description and figure of these, and other varieties of garnet, the reader is referred to Romé de Lisle and Hauy ‡.

Properties.

The texture of garnet, as Bergman first shewed, is foliated §. Its fracture commonly conchoidal. Internal lustre from 4 to 2. Transparency from 2 to 4; sometimes only 1 or 0. Causes single refraction ||. Hardness from 10 to 14. Specific gravity 3.75 to 4.188. Colour usually red. Often attracted by the magnet. Fusible *per se* by the blow-pipe.

Varieties.

Variety 1. Oriental garnet **.—Internal lustre 3 to 4. Transparency 4. Hardness 13 to 14. Specific gravity 4 to 4.188. Colour deep red, inclining to violet ††.

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* Romé De Lisle, ii. 322. and Hauy, *Ann. de Chim.* xvii. 305.

† Hauy, Ibid. 306.

‡ Ibid.

§ *Opusc.* ii. 9.

|| Hauy, *Jour. de Min.* No. xxviii. 260.

** This seems to be the *carbuncle* (ανθραξ) of Theophrastus, and the *carbunculus garamanticus* of other ancient writers.—See Hill's *Theophrastus, περι λιθων*, p. 74. and 77.

†† Hence, according to many, the name *garnet* (in Latin *granatus*), from the resemblance of the stone in colour to the blossoms of the pomegranate,

Class I. Order I.

Variety 2. Common garnet.—Fracture uneven, inclining to the conchoidal. Internal lustre 2 to 3. Transparency from 3 to 0. Hardness 10 to 11; sometimes only 9. Specific gravity 3.75 to 4. Colour commonly deep red, inclining to violet: sometimes verging towards black or olive; sometimes leek-green, brown, yellow.

Variety 3. Amorphous garnet.—Structure slaty. Lustre 2. Transparency 2 to 1. Hardness 11 to 12. Specific gravity 3.89. Colour brownish or blackish red. Found in Sweden, Switzerland, and the East Indies.

Composition.

A specimen of oriental garnet, analysed by Klaproth, contained . . . . . . 35.75 silica
27.25 alumina
36.00 oxide of iron
0.25 oxide of manganese

99.25 *

A specimen of red garnet, analysed by Vauquelin, contained . . . . . . 52.0 silica
20.0 alumina
17.0 oxide of iron
7.7 lime

96.7 †

Sp. 2. Pyrop.

This mineral, which is found in Saxony and Bohemia, has been lately separated from the garnet by Werner, and made a distinct species. It is never found crystallized, but only in round or angular fragments, usually

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* Beitrage, ii. 26.

† *Jour. de Min.* No. xliv. 575.

Genus XIII.
Sali.
Species IV.

nall. Colour deep red*, which passes to orange hen the mineral is exposed to the sun. Very hard. pecific gravity unknown. Fracture conchoidal, and ry brilliant†.

Sp. 3. Melanite.

This mineral was formerly confounded with the arnet. It is found at Frascati in Italy, stuck in lava. is of a black colour, and crystallized like the garnet, a dodecahedron, having its edges truncated. This ineral was analysed by Vauquelin, and yielded

43	silica
16	alumina
20	lime
16	oxide of iron
4	moisture
99‡	

Sp. 4. Thummerstone§.

Yanolite of Lametherie—*Axinite* of Hauy.

History.

This stone was first described by Mr Schreber, who ound it near Balme d'Auris in Dauphiné, and gave it he name of *ſhorl violé* ||. It was afterwards found near hum in Saxony, in consequence of which Werner alled it *thummerstone*.

Crystals.

It is sometimes amorphous; but more commonly rystallized. The primitive form of its crystals is a rectangular prism, whose bases are parallelograms with angles of 101° 32′ and 78° 28′¶. The most usual va-

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* Hence the name πυρωψ.

† *Jour. de Phys.* lii. 227.

‡ *Jour. de Min.* No. xliv. 573.

§ Kirwan, i. 273.—Pelletier, *Jour. de Phys.* xxvi. 66.

|| Romé De Lisle, ii. 353.

¶ Hauy, *Jour. de Min.* No. xxviii. 264.

riety is a flat rhomboidal parallelopiped, with two of its opposite edges wanting, and a small face in place of each *. The faces of the parallelopiped are generally streaked longitudinally.

Properties.

The texture of thummerstone is foliated. Its fracture conchoidal. Lustre 2. Transparency, when crystallized, 3 to 4; when amorphous, 2 to 1. Causes simple refraction†. Hardness 10 to 9. Specific gravity 3.2956. Colour clove brown; sometimes inclining to red, green, grey, violet, or black. Before the blow-pipe it froths like zeolite, and melts into a hard black enamel. With borax it exhibits the same phenomena, or even when the stone is simply heated at the end of a pincer. ‡.

Composition.

A specimen of thummerstone, analysed by Klaproth, contained . . . . .

52.7	silica
25.6	alumina
9.4	lime
9.6	oxide of iron with a trace of manganese
97.3 §	

A specimen, analysed by Vauquelin, contained

44	silica
18	alumina
19	lime
14	oxide of iron
4	oxide of manganese
99 ‖	

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* Romé De Lisle, ii. 353.

† Hauy, *Jour. de Min.* xxviii. 264.

‡ Vauquelin, *Jour. de Min.* No. xxiii. 1.

§ Beitrage, ii. 126.

‖ *Jour. de Min.* ibid.

Genus XIII.
SALI.
Species V.

Sp. 5. Prehnite [*].

History.

Though this stone had been mentioned by Sage [†], omé de Lisle [‡], and other mineralogists, Werner was e first who properly distinguished it from other mine- ls, and made it a distinct species. The specimen hich he examined was brought from the Cape of ood Hope by Colonel Prehn; hence the name *preh- ite*, by which he distinguished it. It was found near unbarton by Mr Grotche [§]; and since that time it as been observed in other parts of Scotland.

Crystals.

It is both amorphous and crystallized. The crystals re in groups, and confused: they seem to be four- ided prisms with dihedral summits [‖]. Sometimes they re irregular six-sided plates, and sometimes flat rhom- oidal parallelopipeds.

Properties.

Its texture is foliated. Fracture uneven. Internal stre pearly, scarcely 2. Transparency 3 to 2. Hard- ess 9 to 10. Brittle. Specific gravity 2.6969 [¶]. Co- our apple green, or greenish grey. Before the blow- ipe it froths more violently than zeolite, and melts into brown enamel. A specimen of prehnite, analysed by laproth, was composed of

Composition.

43.83	silica
30.33	alumina
18.33	lime
5.66	oxide of iron
1.16	air and water
99.31 [**]	

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[*] Kirwan, i. 274.—Hassenfratz, *Jour. de Phys.* xxxii. 81.—Sage, ibid. xiv. 446.—Klap. *Beob. der Berl.* 2 Baud. 211.; and *Ann. de Chim.* i. 201.

[†] *Miner.* i. 232.

[‡] *Crystallog.* ii. 275.

[§] *Ann. de Chim.* i. 213.

[‖] Hauy, *Jour. de Min.* No. xxviii. 277.

[¶] Hauy, ibid.

[**] *Ann. de Chim.* i. 208.

Whereas Mr Hassenfratz found in another specimen

50.0	silica
20.4	alumina
23.3	lime
4.9	iron
.9	water
.5	magnesia
100.0 *	

Sp. 6. Thallite.

Green shorl of Dauphiné of De Lisle †—*Delphinite* of Saussure.

This stone is found in the fissures of mountains; and hitherto only in Dauphiné and on Chamouni in the Alps.

Crystals. It is sometimes amorphous, and sometimes crystallized. The primitive form of its crystals is a rectangular prism, whose bases are rhombs with angles of 114° 37′, and 65° 23′ ‡. The most usual variety is an elongated four-sided prism (often flattened), terminated by four-sided incomplete pyramids; sometimes it occurs in regular six-sided prisms §. The crystals are often very slender.

Properties. Its texture appears fibrous. Lustre inconsiderable. Transparency 2 to 3, sometimes 4; sometimes nearly opaque. Causes single refraction. Hardness 9 to 10. Brittle. Specific gravity 3.4529 to 3.46. Colour dark green ||. Powder white or yellowish green, and feels dry. It does not become electric by heat. Be-

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* *Ann. de Chim.* i. 208. and *Jour. de Phys.* No. xxxii. 81.

† *Crystallog.* ii. 401.

‡ Hauy, *Jour. de Min.* No. xxviii. 271.

§ Romé de Lisle, ibid. and Hauy, *Jour. de Min.* No. xxx. 415.

|| Hence the name *thallite*, given it by Lametherie, from θαλλος, a *green leaf.*

Genus XIV.
1. AMS.
Species I.

ore the blow-pipe, froths and melts into a black slag. Vith borax melts into a green bead [*].

Composition.

A specimen of thallite, analysed by Mr Descotils, ontained . . . . .

37	silica
27	alumina
17	oxide of iron
14	lime
1.5	oxide of manganese
96.5 †	

Sp. 7. Skorza.

This is a green coloured mineral, whose specific gra- ity is 3.35. Klaproth found it composed of

43.00	silica
21.00	alumina
14.00	lime
16.50	oxide of iron
0.25	oxide of manganese
94.75 ‡	

GENUS XIV. 1. AMS.

Sp. 1. Cyanite §.

Sappare of Saussure.

This stone was first described by Mr Saussure the son, who gave it the name of *sappare* ||. It is common- y found in granite rocks. The primitive form of its crystals is a four-sided oblique prism, whose sides are nclined at an angle of 103°. The base forms with one

Crystals.

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[*] Hauy and Descotils, *Jour. de Min.* No. xxx. 415.

[†] Ibid. No. xxx. 420.

[‡] *Jour. de Phys.* lii. 39.

[§] Kirwan, i. 209.—Sage, *Jour. de Phys.* xxxv. 39.

[||] *Jour. de Phys.* xxxiv. 213.

Class I. Order I.

side of the prism an angle of 103°; with another, an angle of 77°. It is sometimes crystallized in six-sided prisms[*].

Properties.

Its texture is foliated. Laminæ long. Fragments long, splintery. Lustre pearly, 2 to 3. Transparency of the laminæ 3. Causes single refraction[†]. Hardness 6 to 9. Brittle. Specific gravity from 3.092 to 3.622[‡]. Feels somewhat greasy. Colour milk white, with shades of sky or prussian blue[§]; sometimes bluish grey; sometimes partly bluish grey, partly yellowish or greenish grey.

Composition.

Before the blow-pipe it becomes almost perfectly white, but does not melt. According to the analysis of Saussure, it is composed of

66.92 alumina
13.25 magnesia
12.81 silica
5.48 iron
1.71 lime

100.17[‖].

Cyanite has also been analysed by Struvius and Hermann, who agree with Saussure as to the ingredients; but differ widely from him and one another as to the proportions.

Struvius.	Hermann.
5.5	30 alumina
30.5	39 magnesia
51.5	23 silica
5.0	2 iron
4.0	3 lime
96.5[¶]	97[**]

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[*] Hauy, *Jour. de Min.* No. xxviii. 282.

[†] Hauy, Ibid.

[‡] Kirwan.

[§] Hence the name *cyanite*, imposed by Werner.

[‖] *Jour. de Phys.* xxxiv. 213.

[¶] Crell's *Annals*, 1790.

[**] Ibid.

Genus XV. Msai. Species I.

Genus XIV. 2. MSA.

Sp. 2. Serpentine*.

Properties.

This stone is found in amorphous masses. Its frac- ure is splintery. Lustre 0. Opaque. Hardness 6 to . Specific gravity 2.2645 to 2.709. Feels rather oft, almost greasy. Generally emits an earthy smell hen breathed upon. Its colours are various shades of reen, yellow, red, grey, brown, blue: commonly one r two colours form the ground, and one or more ap- ear in spots or veins†.

Before the blow-pipe it hardens and does not melt.

Composition.

A specimen of serpentine, analysed by Mr Chenevix, ontained . . .

34.5	magnesia
28.0	silica
23.0	alumina
4.5	oxide of iron
0.5	lime
10.5	water
101.0‡	

Genus XV. Msai.

Sp. 1. Potstone§.

Properties.

This stone is found in nests and beds, and is always morphous. Its structure is often slaty. Texture un- ulatingly foliated. Lustre from 1 to 3. Transpa- ency from 1 to 0; sometimes 2. Hardness 4 to 6.

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[*] Kirwan, i. 156.—Margraff, *Mem. Berlin*, 1759, p. 3.—Bayen, *Jour. Phys.* xiii. 46.—Mayer, Crell's *Annals*, 1789, ii. 416.

[†] Hence the name *serpentine*, given to this stone from a supposed re- mblance in colours to the skin of serpent.

[‡] *Ann. de Chim.* xxviii. 199.

[§] Kirwan, i. 155.

Brittle. Specific gravity from 2.8531 to 3.023. Feels greasy. Sometimes absorbs water. Colour grey with a shade of green, and sometimes of red or yellow; sometimes leek green; sometimes speckled with red.

Potstone is not much affected by fire; and has therefore been made into utensils for boiling water; hence its name.

According to Wiegleb, the potstone of Como contains

Composition.

38 magnesia
38 silica
7 alumina
5 iron
1 carbonat of lime
1 fluoric acid

90

Sp. 2. Chlorite*.

This mineral enters as an ingredient into different mountains. It is sometimes amorphous, and sometimes crystallized in oblong, four-sided, acuminated crytals.

Properties.

Its texture is foliated. Its lustre from 0 to 2. Opaque. Hardness from 4 to 6; sometimes in loose scales. Colour green.

Varieties.

Variety 1. Farinaceous chlorite.——Composed of scales scarcely cohering, either heaped together, or investing other stones. Feels greasy. Gives an earthy smell when breathed on. Difficult to pulverise. Colour grass green; sometimes greenish brown; sometimes dark green, inclining to black. Streak white. When the powder of chlorite is exposed to the blow-

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* Kirwan, i. 147.

Genus XV.
MSAL.
Species II.

pipe it becomes brown. Before the blow-pipe, farinaceous chlorite froths and melts into a dark brown glass; with borax it forms a greenish brown glass*.

Variety 2. Indurated chlorite.—This variety is crystallized. Lustre 1. Hardness 6. Feel meagre. Colour dark green, almost black. Streak mountain green.

Variety 3. Slaty chlorite—Structure slaty. Fragments flatted. Internal lustre 1 to 2. Hardness 5. Colour greenish grey, or dark green inclining to black. Streak mountain green.

Composition.

A specimen of the first variety, analysed by Vauquelin, contained . . . .

43.3	oxide of iron
26.0	silica
15.5	alumina
8.0	magnesia
2.0	muriat of potass
4.0	water
98.8 †	

A specimen of the same variety yielded Mr Hæpner

12.92	oxide of iron
37.50	silica
4.17	alumina
43.75	magnesia
1.66	lime
100.00 ‡	

A specimen of the second variety, analysed by the same chemist, contained

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* Vauquelin, *Jour. de Min.* No. xxxix. 167.

† *Ann. de Chim.* xxx. 106.

‡ Saussure's *Voyages*, ii. 133.

Class I.
Order I.

10.15	oxide of iron
41.15	silica
6.13	alumina
39.47	magnesia
1.50	lime
1.50	air and water
99 9[*]	

On the supposition that these analyses are accurate, the enormous difference between them is a demonstration that chlorite is not a chemical combination, but a mechanical mixture.

GENUS XVI. SLAM.

Sp. 1. Siliceous spar.

This stone has been found in Transylvania. It is crystallized in four or six-sided prisms, channelled transversely, and generally heaped together. Its texture is fibrous. Its lustre silky, 2. Its colours white, yellow, green, light blue. According to Bindheim, it contains

61.1	silica
21.7	lime
6.6	alumina
5.0	magnesia
1.3	oxide of iron
3.3	water.
99.0[†]	

GENUS XVII. 1. SAMLI.

Sp. 1. Argillite[‡].

Argillaceous shistus—Common slate.

This stone constitutes a part of many mountains.

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[*] Crell's *Annals*, 1790, p. 56.

[†] Berg. vi. 104.

[‡] Kirwan, i. 234.

Properties.

Its structure is slaty. Its texture foliated. Fracture splintery. Fragments often tabular. Lustre most commonly silky, 2; sometimes 0. Transparency from 0 to 1. Hardness from 5 to 8. Specific gravity from 2.67 o 2.88. Does not adhere to the tongue. Gives a clear ound when struck. Often imbibes water. Streak white or grey. Colour most commonly grey, with a shade of blue, green, or black; sometimes purplish, yellowsh, mountain green, brown, bluish black; sometimes striped or spotted with a darker colour than the ground.

It is composed, according to Kirwan, of silica, alumina, magnesia, lime, oxide of iron. In some varieties the lime is wanting. Several varieties contain a considerable quantity of carbonaceous matter.

GENUS XVIII. SLACMI.

Sp. 1. Smaragdite.

This stone was called *smaragdite* by Mr Saussure, from some resemblance which it has to the emerald. Never crystallized. Its texture is foliated. Easily diided into plates. The laminæ are inflexible. Fracture even. Hardness 7. Specific gravity 3. Colour in some ases fine green; in others it has the grey colour and metallic lustre of mica: it assumes all the shades of coour between these two extremes *.

According to the analysis of Vauquelin, it is composed of

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* Hauy, *Jour. de Min.* No. xxviii. 272.

Class I.
Order I.

50.0	silica
13.0	lime
11.0	alumina
7.5	oxide of chromum
6.0	magnesia
5.5	oxide of iron
1.5	oxide of copper
94.5[*]	

GENUS XIX. SM.

Sp. 1. Kiffekil[†].

Myrsen—Seafroth.

This mineral is dug up near Konie in Natolia, and is employed in forming the bowls of Turkish tobacco pipes The sale of it supports a monastery of dervises established near the place where it is dug. It is found in a large fissure six feet wide, in grey calcareous earth. The workmen assert that it grows again in the fissure[‡], and puffs itself up like froth[§]. This mineral, when fresh dug, is of the consistence of wax; it feels soft and greasy; its colour is yellow; its specific gravity 1.600[||]: when thrown on the fire it sweats, emits a fetid vapour, becomes hard, and perfectly white.

According to the analysis of Klaproth, it is composed of . . . . . .

50.50	silica
17.25	magnesia
25.00	water
5.00	carbonic acid
.50	lime.
98.25[¶]	

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[*] *Ann. de Chim.* xxx. 106.

[†] Kirwan's *Min.* i. 144.

[‡] Reignegg, *Philos. Mag.* iii. 165.

[§] Hence the name *kiff-kil*, or rather *keff-kelli*, "clay froth," or "light clay."

[||] Klaproth.

[¶] Beitrage, ii. 172.

Genus XIX.
Sm.
Species II.

Sp. 2. Steatites *.

Though this mineral was noticed by the ancients, little attention was paid to it by mineralogists, till Mr Pott published his experiments on it in the Berlin Memoirs for 1747.

Properties.

It is usually amorphous, but sometimes it is crystallized in six-sided prisms. Its texture is commonly earthy, but sometimes foliated. Lustre from 0 to 2. Transparency from 0 to 2. Hardness 4 to 7. Specific gravity from 2.61 to 2.794 †. Feels greasy. Seldom adheres to the tongue. Colour usually white or grey; often with a tint of other colours; the foliated commonly green. Does not melt *per se* before the blowpipe.

Varieties.

Variety 1. Semi-indurated steatites. Texture earthy. Fracture sometimes coarse splintery. Lustre 0. Transparency 0, or scarce 1. Hardness 4 to 5. Absorbs water. Takes a polish from the nail. Colour white, with a shade of grey, yellow, or green; sometimes pure white; sometimes it contains dendritical figures; and sometimes red veins.

Variety 2. Indurated steatites. Fracture fine splintery, often mixed with imperfectly conchoidal. External lustre 2 to 1, internal 0. Transparency 2. Often has the feel of soap. Absorbs water. Colour yellowish or greenish grey; often veined or spotted with deep yellow or red.

Variety 3. Foliated or striated steatites. The texture of this variety is usually foliated; sometimes striated.

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* Kirwan, i. 151.——Pott. *Mem. Berlin*, 1747, p. 57.—Wiegleb, *Jour. de Phys.* xxix. 60.—Lavoisier, *Mem. Par.* 1778, 433.

† Brisson.

Class I. Order I.

Fragments cubiform. Lustre 3. Transparency 2 to 1. Hardness 6 to 7. Colour leek green, passing into mountain green or sulphur yellow. Streak pale greenish grey. When heated to redness, it becomes grey; and at 147° Wedgewood, it forms a grey porous porcelain mass *.

Composition.

A specimen of steatites analysed by Klaproth, contained . . . .

59.5	silica
30.5	magnesia
2.5	iron
5.5	water
98.0 †	

A specimen of white steatites, analysed by Mr Chenevix, contained . . .

60.00	silica
28.50	magnesia
3.00	alumina
2.50	lime
2.25	iron
96.25 ‡	

GENUS XX. MSI.

Sp. 1. Chrysolite §,

Peridot of the French—*Topaz* of the ancients.

The name *chrysolite* was applied, without discrimination, to a great variety of stones, till Werner defined it accurately, and confined it to that stone which the French chemists distinguish by the appellation of *peridot.* This stone is the *topaz* of the ancients; their chrysolite is now called *topaz* ‖.

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* Kirwan, i. 155. † Beitrage, ii. 179. ‡ *Ann. de Chim.* xxviii. 200.

§ Kirwan, i. 262.—Cartheuser, *Min.* 94.—Dolomieu, *Jour. de Min.* No. xxix. 365.—La Metherie, *Nouv. Jour. de Phys.* i. 397.

‖ Plinii, lib. xxxvii. c. 8.

Genus XX.
Msi.
Species I.

Crystals.

Chrysolite is found sometimes in unequal fragments, and sometimes crystallized. The primitive form of its crystals is a right-angled parallelopiped, whose length, breadth, and thickness, are as 5, $\sqrt{8}$, $\sqrt{5}$ [*].

Properties.

The texture of the chrysolite is foliated. Its fracture conchoidal. Its internal lustre from 2 to 4. Its transparency from 4 to 2. Causes double refraction. Hardness 9 to 10. Brittle. Specific gravity from 3.265 to 3.45. Colour green. It is infusible at 150°, but loses its transparency, and becomes blackish grey [†]. With borax it melts without effervescence into a transparent glass of a light green colour. Infusible with microcosmic salt [‡] and fixed alkali [§].

Varieties.

Variety 1. Common chrysolite. Found in Ceylon, and South America, and in Bohemia, amidst sand and gravel [||]. Lustre 3 to 4. Transparency 4 to 3. Colour yellowish green, sometimes verging to olive green, sometimes to pale yellow.

Variety 2. Olive chrysolite. *Olivine* [¶].—Found commonly among traps and basalts; sometimes in small grains, sometimes in pretty large pieces; but it has not been observed in crystals. Lustre 2 to 3. Transparency 3 to 2. Colour olive green.

Composition.

The first variety, according to the analysis of Klaproth, is composed of

41.5	magnesia
38.5	silica
19.0	oxide of iron
99.0 [**]	

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[*] Hauy, *Jour. de Min.* No. xxviii. 281.

[†] Kirwan's *Min.* i. 263.

[‡] Vauquelin, *Ann. de Chim.* xxi. 97.

[§] Kirwan, i. 263.

[||] Coquebert, *Jour. de Min.* No. xxii. 20.

[¶] Kirwan, i. 263.—Le Lievre, *Jour. de Phys.* xxx. 397.

[**] Klaproth's Beitrage, i. 103.

Class I. Order I.

According to that of Vauquelin, it is composed of

51.5	magnesia
38.0	silica
9.5	oxide of iron
99.0 *	

The second variety, according to the analysis of Klaproth, is composed of

37.58	magnesia
50.00	silica
11.75	oxide of iron
.21	lime
99.54 †	

Sp. 2. Jade ‡.

This stone was formerly called *lapis nephriticus*, and was much celebrated for its medical virtues. It is found in Egypt, China, America, and in the Siberian and Hungarian mountains. It is sometimes adhering to rocks, and sometimes in detached round pieces.

Properties

Its surface is smooth. Its fracture splintery. External lustre 0, or scarce 1; internal waxy, 1. Transparency from 2 to 1. Hardness 10. Not brittle. Specific gravity from 2.95 to 2.9829; or, according to Saussure, to 3.389. Feels greasy. Looks as if it had imbibed oil. Colour dark leek green, or verging towards blue; in some prominencies inclining to greenish or bluish white. When heated it becomes more transparent and brittle, but it is infusible *per se*. According to Hœpfner, it is composed of

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* *Ann. de Chim.* xxi. 97.

† Beitrage, i. 112.

‡ Kirwan, i. 171.—Bartolin, *De Lapide Nephritico*.—Lehmann, *Nov. Comm. Petropol.* x. 381.—Hœpfner, *Hist. Nat. de la Suisse*, i. 251.

47	silica
38	carbonat of magnesia
9	iron
4	alumina
2	carbonat of lime
100	

This is the stone which the inhabitants of New Zealand make into hatchets and other cutting instruments.

GenusXXI. Sml. Species I.

Genus XXI. Sml.

Sp. 1. Asbestus*.

This mineral was well known to the ancients. They even made a kind of cloth from one of the varieties, which was famous among them for its incombustibility. It is found abundantly in most mountainous countries, and nowhere more abundantly than in Scotland.

It is commonly amorphous. Its texture is fibrous. Its fragments often long splintery. Lustre from 0 to 1; sometimes 3, and then it is metallic. Transparency from 0 to 2. Hardness from 3 to 7. Specific gravity from 2.7 to 0.6806. Absorbs water. Colour usually white or green. Fusible *per se* by the blow-pipe.

Varieties.

Variety 1. Common asbestus.—Lustre 2 to 1. Transparency 1. Hardness 6 to 7. Specific gravity 2.577 to 2.7. Feels somewhat greasy. Colour leek green; sometimes olive or mountain green; sometimes greenish or yellowish grey. Streak grey. Powder grey.

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* Kirwan, i. 159.—Bergman, iv. 160.—Plot, *Phil. Trans.* xv. 1051.—Nebel, *Jour. de Phys.* ii. 62.—Ibid. iii. 367.

Class I. Order I.

Variety 2. Flexible asbestus. *Amiantus*—Composed of a bundle of threads slightly cohering. Fibres flexible. Lustre 1 to 2, sometimes 3. Transparency 1 to 2, sometimes 0. Hardness 3 to 4. Specific gravity, before it absorbs water, from 0.9088 to 2.3134; after absorbing water, from 1.5662 to 2.3803 *. Feels greasy. Colour greyish or greenish white; sometimes yellowish or silvery white, olive or mountain green, pale flesh red, and mountain yellow.

Variety 3. Elastic asbestus. *Mountain cork*—This variety has a strong resemblance to common cork. Its fibres are interwoven. Lustre commonly 0. Opaque. Hardness 4. Specific gravity, before absorbing water, from 0.6806 to 0.9933; after absorbing water, from 1.2492 to 1.3492. Feels meagre. Yields to the fingers like cork, and is somewhat elastic. Colour white; sometimes with a shade of red or yellow; sometimes yellow or brown.

Composition.

A specimen of the first variety from Dalecarlia, analysed by Bergman, contained

63.9	silica
16.0	carbonat of magnesia
12.8	carbonat of lime
6.0	oxide of iron
1.1	alumina
99.8 †	

A specimen of the second variety yielded to the same chemist . . . .

64.0	silica
17.2	carbonat of magnesia
13.0	carbonat of lime
2.7	alumina
2.2	oxide of iron
100.0 ‡	

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* Brisson.

† *Opusc.* iv. 170.

‡ Ibid p. 163.

Gen. XXII.
1. Silm.
Species I.

A specimen of the third variety contained, according to the same analysis, 56.2 silica
26.1 carbonat of magnesia
12.7 carbonat of lime
3.0 iron
2.0 alumina

100.0*

Twelve different specimens of asbestus, analysed by Bergman, yielded the same ingredients, differing a little in their proportions†.

Sp 2. Asbestinite‡.

This stone is amorphous. Texture foliated or broad striated. Lustre silky, 3. Transparency 1 to 2. Hardness 5 to 6. Specific gravity from 2.806 to 2.880. Colour white, with shades of red, yellow, green, or blue. At 150° Wedgewood it melts into a green glass.

GENUS XXII. 1. SILM.

Sp. 1. Augite.

Pyroxen of Hauy.—*Volcanite* of Delametherie.

This mineral is only found in basalt and lava. It is usually in grains or in small crystals. The primitive form of its crystals is an oblique angled prism, whose bases are rhombs with angles of 92° 18′ and 37° 42′§. It generally crystallizes in six or eight sided prisms, terminated by dihedral summits||. Its texture is foliated. Hardness 9. Fracture imperfectly conchoidal and brilliant. Usually somewhat transparent. Colour deep green, or greenish black. Powder greenish

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* *Opusc.* iv. 170.

† Ibid. p. 175.

‡ Kirwan, i. 165.

§ Hauy, *Jour. de Min.* xxviii. 269.

|| De Lisle, ii. 398.

grey. Specific gravity 3.47. Commonly attracted by the magnet[*]. Scarcely fusible by the blow-pipe[†]. With borax it melts into a yellowish glass, which appears red while it is hot[‡].

According to the analysis of Vauquelin, it is composed of . . . . . 52.00 silica
14.66 oxide of iron
13.20 lime
10.00 magnesia
3.33 alumina
2.00 oxide of manganese

95.19[§]

Sp. 2. Asbestoid[||].

This stone has obtained its name from its similarity to common asbestus. It is amorphous. Its texture is foliated or striated. Its lustre common or glassy, from 2 to 3. Transparency from 0 to 1. Hardness 6 to 7. Specific gravity from 3 to 3.31. Colour olive or leek green; when decomposing, brown. Before the blow-pipe it melts *per se* into a brown globule. With borax it forms a violet-coloured globule verging towards hyacinth[¶]. According to the analysis of Mr Macquart, it is composed of 46 silica
20 oxide of iron
11 lime
10 oxide of manganese
8 magnesia

95[**]

Properties.

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[*] Ferber.
[†] Le Lievre.
[‡] Vauquelin.
[§] *Jour. de Min.* xxxix. 172.
[||] Kirwan, i. 166.
[¶] Macquart, *Ann. de Chim.* xxii. 83.
[**] Ibid.

There is a variety of this species which Kirwan calls metalliform asbestoid. Its lustre is semimetallic, 3. Opaque. Hardness 8 to 9. Specific gravity 3.356. Colour grey, sometimes inclining to red*.

GENUS XXII. 2. SMIL.

Sp. 3. Shorlaceous actinolite†.—*Rayonnante.*

This stone crystallizes in four or six sided prisms, thicker at one end than the other; hence it has been called by the Germans *strahlstein*, "arrow-stone." The crystals sometimes adhere longitudinally. Fracture hackly. External lustre glassy, 3 to 4; internal, 1 to 2. Transparency from 2 to 3; sometimes 1. Hardness from 7 to 10. Specific gravity 3.023 to 3.45. Colour leek or dark green.

This stone is often the matrix of iron, copper, and tin ores.

Sp. 4. Lamellar actinolite‡.

This stone resembles hornblende. It is amorphous. Texture foliated. Lustre various in different places. Transparency 0, or scarce 1. Specific gravity 2.916. Colour dark yellowish or greenish grey.

Sp. 5. Glassy actinolite§.

Properties.

This stone is found amorphous, composed of fibres adhering longitudinally, or in slender four or six-sided prisms. Texture fibrous. Fragments long splintery, so sharp that they can scarcely be handled without injury. External lustre glassy or silky, 3 to 4; internal 0. Transparency 2. Exceedingly brittle. Specific gravity 2.95 to 3.493. Colour leek green; sometimes verging towards greenish or silver white; sometimes

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* Kirwan, i. 167.

† Ibid. p. 168.

‡ Ibid. 167.

§ Ibid. p. 168.

Class I. Order I.

stained with yellowish or brownish red. According to Bergman it is composed of 72.0 silica

12.7 carbonat of magnesia
6.0 carbonat of lime
7.0 oxide of iron
2.0 alumina

99.7 *.

Sp. 6. Idocrase.

Hyacinthine of Delametherie—*Sorlo piceo* of Giœni.

Properties.

This mineral is found in lava, and was formerly confounded with the hyacinth. Its colour is brown or greenish, and it is usually crystallized in rectangular eight sided prisms, or rather four-sided prisms with their edges truncated. The primive form of its crystals is the cube. Specific gravity from 3.39 to 3.409. Scratches glass. Lustre 2. Fracture imperfectly conchoidal. Transparent. Causes double refraction. Before the blow-pipe melts into a yellowish glass. According to the analysis of Stucke, it is composed of

Composition.

26.5 silica
40.2 magnesia
16.2 oxide of iron
16.0 lime

98.9 †

GENUS XXIII. SL.

Sp. 1. Shistose hornstone ‡.

The structure of this stone is slaty. Lustre from 0. to 1. Commonly opaque. Hardness 9 to 10. Specific gravity from 2.596 to 2.641. Colour dark bluish or blackish grey. Infusible *per se*.

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* *Opusc.* iv. 171. † *Jour. de Phys.* xlvi. 69. ‡ Kirwan, i. 305.

Gen. XXIII.
Sl.
Species II.
Varieties.

Variety 1. Siliceous shistus.—Commonly intersected by reddish veins of iron stone. Fracture splintery. Lustre 0. Transparency from 0 to 1.

Variety 2. Basanite or Lydian stone.—Commonly intersected by veins of quartz. Fracture even; sometimes inclining to conchoidal. Lustre scarce 1. Hardness 10. Specific gravity 2.596. Powder black. Colour greyish black.

This, or a stone similar to it, was used by the ancients as a touchstone. They drew the metal to be examined along the stone, and judged of its purity by the colour of the metallic streak. On this account they called it βασανος, *the trier*, They called it also *Lydian stone;* because, as Theophrastus informs us, it was found most abundantly in the river Tmolus in Lydia*.

Composition.

A specimen of the first variety, analysed by Wiegleb, contained . . .

75.0	silica
10.0	lime
4.6	magnesia
3.5	iron
5.2	carbon
98.3	

This species is rather a mechanical mixture than a chemical combination.

Sp. 2. Tremolite.

This mineral, found in the valley of Tremola in the Alps, has been described by Saussure†, and seems to be very intimately connected with the minerals arranged under the second division of the last Genus. It is white with a shade of green or red, and is either cry-

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* Hill's *Theophrastus* περι λιθων, p. 190.

† Saussure's *Voyages*, iv. 105.

stallized or in irregular masses. Its crystals are four-sided oblique prisms, with angles of 67° and 113°. Specific gravity from 2.9 to 3.2. Texture fibrous. Fracture conchoidal. Fibres rigid, so that it irritates the skin when rubbed against it. Cuts glass. Lustre considerable. Somewhat transparent. Fibres easily separated, so that it appears soft. Phosphoresces when two pieces are rubbed in the dark against each other. Von Berchen and Struve have divided this species into five varieties, namely, the common, glassy, asbestiform, silky, and grey. A spesimen analysed by Klaproth contained

Composition.

65.0	silica
38.0	lime
0.5	magnesia
0.5	oxide of iron
6.0	water and carbonic acid
100.0	

Genus XXIV. Zs.

Sp. 1. Zircon *.

Jargon—Hyacinth.

This stone is brought from Ceylon, and found also in France, Spain, and other parts of Europe. It is commonly crystallized. The primite form of its crystals is an octahedron, composed of two four-sided pyramids applied base to base, whose sides are isosceles triangles.

Crystals.

The inclination of the sides of the same pyramid to each other is 124° 12′; the inclination of the sides of one pyramid to those of another 82° 50′. The solid angle at the apex is 73° 44′ †. The varieties of the crystalline forms of zircon amount to seven. In some

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* Kirwan, i. 257. and 333.

† Hauy, *Jour. de Min.* No. xxvi. 91.

cases there is a four-sided prism interposed between the pyramids of the primitive form; sometimes all the angles of this prism are wanting, and two small triangular faces in place of each; sometimes the crystals are dodecahedrons, composed of a flat four-sided prism with hexagonal faces, terminated by four-sided summits with rhomboidal faces; sometimes the edges of this prism, sometimes the edges where the prism and summit join, and sometimes both together, are wanting, and we find small faces in their place. For an accurate description and figure of these varieties, the reader is referred to Mr Hauy *.

Properties.

The texture of the zircon is foliated. Internal lustre 3. Transparency from 4 to 2. Causes a very great double refraction. Hardness from 10 to 16. Specific gravity from 4.2 to 4.165 †. Colour commonly reddish or yellowish; sometimes it is limpid.

Before the blow pipe it loses its colour, but not its transparency. With borax it melts into a transparent glass. Infusible with fixed alkali and microcosmic salt.

Varieties.

1. The variety formerly called *hyacinth* is of a yellowish red colour, mixed with brown. Its surface is smooth. Its lustre 3. Its transparency 3 to 4.

2. The variety formerly called *jargon of Ceylon* is either grey, greenish, yellowish brown, reddish brown, or violet. It has little external lustre. It is sometimes nearly opaque.

Composition.

The first variety, according to the analysis of Vauquelin, is composed of

64.5	zirconia
32.0	silica
2.0	oxide of iron
95.5 ‡	

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* Hauy. *Jour. de Min.* No. xxvi. 91.

† Ibid.

‡ Ibid. p. 106.

Class I. Order I.

A specimen analysed by Klaproth contained

70.0	zirconia
25.0	silica
0.5	oxide of iron
95.5 *	

The second variety, according to Klaproth, who discovered the component parts of both these stones, contains . . . .

68.0	zirconia
31.5	silica
0.5	nickel and iron
100.0 †	

GENUS XXV. YSI.

Sp. 1. Gadolinite.

This mineral was first observed by Captain Arhenius, lodged in a white felspar in the quarry of Ytterby in Sweden, and received the name of Gadolinite, because Gadolin was the chemist who first ascertained its composition. It occurs in thick kidney-form masses, or in parallel plates. Its colour is black; that of its powder greenish grey. Fracture conchoidal and glassy. Opake. Scratched by iron, and in some cases even by the nail. Attracted by the magnet. Before the blow-pipe decrepitates and melts into a black blistered slag. Forms with borax a yellowish transparent glass; with soda a white transparent glass ‡. According to the analysis of Vauquelin, it is composed of

Properties.

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* Beitrage, i. 231. † Ibid. i. 219.

‡ Ekeberg, Crell's *Annals*, 1799. ii. 67.

Gen. XXV. Ysi. Species I.

35.0	yttria
25.5	silica
25.0	oxide of iron
2.0	lime
2.0	oxide of manganese
10.5	water and carbonic acid
100.0 *	

Klaproth on the other hand found

59.75	yttria
21.25	silica
18.00	oxide of iron
0.50	alumina
99.50 †	

This last analysis does not differ much from that which Ekeberg had before published.

ORDER II. SALINE STONES.

UNDER this Order I comprehend all the minerals which consist of an earthy basis combined with an acid. They naturally divide themselves into five genera. I hall describe them in the following order.

Arrangement.

I. CALCAREOUS SALTS.
1. Carbonat of lime,
2. Sulphat of lime,
3. Phosphat of lime,
4. Fluat of lime,
5. Borat of lime,
6. Arseniat of lime.

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* *Ann. de Chim.* xxxvi. 152.

† Ibid. xxxvii. 87.

Class I.
Order II.

II. BARYTIC SALTS.
  1. Carbonat of barytes,
  2. Sulphat of barytes.

III. STRONTIAN SALTS.
  1. Carbonat of strontian,
  2. Sulphat of strontian.

IV. MAGNESIAN SALTS.
  Sulphat of magnesia.

V. ALUMINOUS SALTS.
  1. Alum,
  2. Mellite,
  3. Chriolite.

GENUS I. CALCAREOUS SALTS.

This genus comprehends all the combinations of lime and acids which form a part of the mineral kingdom.

Sp. 1. Carbonat of lime.

No other mineral can be compared with carbonat of lime in the abundance with which it is scattered over the earth. Many mountains consist of it entirely, and hardly a country is to be found on the face of the globe where, under the names of limestone, chalk, marble, spar, it does not constitute a greater or smaller part of the mineral riches.

Crystals. It is often amorphous, often stalactical, and often crystallized. The primitive form of its crystals is a parallelopiped, whose sides are rhombs, with angles of 77° 30′ and 102° 30′. Its integrant molecules have the same form. The varieties of its crystals amount to more than 40. For a description and figure of which the reader is referred to *Romé de Lisle* * and *Hauy* †.

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* *Crystallog.* i. 497.

† *Essai d'une Theorie,* &c. p. 75.—*Jour. de Phys.* 1793, August, p. 114

Genus I.
Species I.

Properties.

When crystallized, its texture is foliated; when amorphous, its texture is sometimes foliated, sometimes striated, sometimes granular, and sometimes earthy. Its lustre varies from 0 to 3. Transparency from 0 to 4. It causes double refraction; and it is the only mineral which causes double refraction through two parallel faces of the crystal. Hardness from 3 to 9. Specific gravity from 2.315 to 2.78. Colour, when pure, white. Effervesces violently with muriatic acid, and dissolves completely, or leaves but a small residuum. The solution is colourless.

This species occurs in a great variety of forms; and therefore has been subdivided into numerous varieties. All these may be conveniently arranged under two general divisions.

I. Soft carbonat of lime.

Varieties.

Variety 1. Agaric mineral. *Mountain milk*, or *mountain meal* of the Germans.—This variety is found in the clefts of rocks, or the bottom of lakes. It is nearly in the state of powder; of a white colour, sometimes with a shade of yellow; and so light that it almost floats on water.

Variety 2. Chalk.—The colour of chalk is white, sometimes with a shade of yellow. Lustre 0. Opaque. Hardness 3 to 4. Specific gravity from 2.315 to 2.657. Texture earthy. Adheres slightly to the tongue. Feels dry. Stains the fingers, and marks. Falls to powder in water. It generally contains about $\frac{2}{100}$ of alumina, and $\frac{3}{100}$ of water; the rest is carbonat of lime.

Variety 3. Arenaceous limestone.—Colour yellow-

—*Jour. de Hist. Nat.* 1792, February, p. 148.—*Ann. de Chim.* xvii. 249. &c.—*Jour. de Min.* No. xxviii. 304.

Class I.
Order II.

ish white. Lustre 1. Transparency 1. So brittle that small pieces crumble to powder between the fingers. Specific gravity 2.742. Phosphoresces in the dark when scraped with a knife, but not when heated. It consists almost entirely of pure carbonat of lime.

Variety 4. Testaceous tufa.—The colour of this variety is yellowish or greyish white. It is exceedingly porous and brittle; and is either composed of broken shells, or resembles mortar containing shells; or it consists of fistulous concretions variously ramified, and resembling moss.

II. Indurated carbonat of lime.

Variety 1. Compact limstone.—The texture of this variety is compact. It has little lustre; and is most commonly opaque. Hardness 5 to 8. Specific gravity 1.3864 to 2.72. Colour grey, with various shades of other colours. It most commonly contains about $\frac{1}{10}$th of alumina, oxyd of iron, &c.; the rest is carbonat of lime. This variety is usually burnt as lime.

Variety 2. Granularly foliated limstone.—Structure sometimes slaty. Texture foliated and granular. Lustre 2 to 1. Transparency 2 to 1. Hardness 7 to 8. Specific gravity 2.71 to 2.8376. Colour white, of various shades from other colours.

Variety 3. Sparry limestone.—Structure sparry. Texture foliated. Fragments rhomboidal. Lustre 2 to 3. Transparency from 2 to 4; sometimes 1. Hardness 5 to 6. Specific gravity from 2.693 to 2.718. Colour white: often with various shades of other colours. To this variety belong all the crystals of carbonat of lime.

Variety 4. Striated limestone.—Texture striated or fibrous. Lustre 1 to 0. Transparency 2 to 1. Hardness 5 to 7. Specific gravity commonly from 2.6 to 2.77. Colour various.

Variety 5. Swine stone.—Texture often earthy. Fracture often splintery. Lustre 1 to 0. Transparency 0 to 1. Hardness 6 to 7. Specific gravity 2.701 to 2.7121. Colour dark grey, of various shades. When scraped or pounded, it emits an urinous or garlic smell.

Variety 6. Oviform—This variety consists of a number of small round bodies, closely compacted together. Lustre 0. Transparency 0 or 1. Hardness 6 to 7.

Sp. 2. Sulphat of lime.

Gypsum—Selenite.

This mineral is found abundantly in Germany, France, England, Italy, &c.

Crystals.

It is found sometimes in amorphous masses, sometimes in powder, and sometimes crystallized. The primitive form of its crystals, according to Romé de Lisle, is a dodecahedron, which may be conceived as two four-sided pyramids, applied base to base, and which, instead of terminating in pointed summits, are truncated near their bases; so that the sides of the pyramids are trapeziums, and they terminate each in a rhomb. These rhombs are the largest faces of the crystal. The angles of the rhombs are 52° and 158°. The inclination of two opposite faces of one pyramid to the two similar faces of the other pyramid is 145°, that of the other faces 110 *. Sometimes some of the faces are elongated: sometimes it crystallizes in six-sided prisms, terminated by three or four-sided summits, or by an indeterminate number of curvilinear faces. For a descrip-

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* *Crystallog.* i. 144.

Class I. Order II.

tion and figure of these varieties, the reader is referred to Romé de Lisle *.

Properties

The texture of sulphat of lime is most commonly foliated. Lustre from 0 to 4. Transparency from 0 to 4. It causes double refraction. Its hardness does not exceed 4. Its specific gravity from 1.872 to 2.311. Colour commonly white or grey.

Before the blow-pipe it melts into a white enamel, provided the blue flame be made to play upon the edges of its laminæ. When the flame is directed against its faces, the mineral falls into powder †.

It does not effervesce with muriatic acid, except it be impure; and it does not dissolve in it.

The following varieties of this mineral are deserving of attention.

Varieties.

Variety 1. Broad foliated sulphat—Texture broad foliated. Lustre glassy, from 4 to 2. Transparency from 4 to 3. Hardness 4. Specific gravity 2.311. Colour grey, often with a shade of yellow.

Variety 2. Grano-foliated sulphat.—Texture foliated, and at the same time granular; so that it easily crumbles into powder. Lustre 2 to 3. Transparency 2 to 3. Hardness 4 to 3. Specific gravity from 2.274 to 2.310. Feels soft. Colour white or grey, often with a tinge of yellow, blue, or green; sometimes flesh red, brown, or olive green.

Variety 3. Fibrous sulphat.—Texture fibrous. Fragments long splintery. Lustre 2 to 3. Transparency 2 to 1; sometimes 3. Hardness 4. Brittle. Specific gravity 2.300. Colour white, often with a shade of grey, yellow, or red; sometimes flesh red, and some-

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* *Crystallog.* i. 144.

† Le Lievre, *Jour. de Min.* No. xxviii. 315.

times honey yellow; sometimes several of these colours meet in stripes.

Variety 4. Compact sulphat.—Texture compact. Lustre 1 or 0. Transparency 2 to 1, sometimes 0. Hardness 4. Specific gravity from 1.872 to 2.288. Feels dry but not harsh. Colour white, with a shade of grey, yellow, blue, or green; sometimes yellow; sometimes red; sometimes spotted, striped, or veined.

Variety 5. Farinaceous sulphat.—Of the consistence of meal. Lustre 0. Opaque. Scarcely sinks in water. Is not gritty between the teeth. Feels dry and meagre. Colour white. When heated below redness, it becomes of a dazzling white.

Sp. 3. Phosphat of lime.

Apatite—Phosphorite—Chrysolite of the French.

This substance is found in Spain, where it forms whole mountains, and in different parts of Germany. It is sometimes amorphous, and sometimes crystallized. The primitive form of its crystals is a regular six-sided prism. Its integrant molecule is a regular triangular prism, whose height is to a side of its base as 1 to $\sqrt{2}$[*]. Sometimes the edges of the primitive hexagonal prism are wanting, and small faces in their place; sometimes there are small faces instead of the edges which terminate the prism; sometimes these two varieties are united; sometimes the terminating edges and the angles of the prism are replaced by small faces; and sometimes the prism is terminated by four-sided pyramids[†].

Crystals.

Its texture is foliated. Its fracture uneven, tending to conchoidal. External lustre from 2 to 3; internal, 3 to 2. Transparency from 4 to 2. Causes single re-

Properties.

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[*] Hauy, *Jour. de Min.* No. xxviii. 310.

[†] Hauy, Ibid.

fraction. Hardness 6 to 7. Brittle. Specific gravity from 2.8249 to 3.218. Colour commonly green or grey; sometimes brown, red, blue, and even purple.

It is infusible by the blow-pipe. When its powder is thrown upon burning coals, it emits a yellowish green phosphorescent light. It is soluble in muriatic acid without effervescence or decomposition, and the solution often becomes gelatinous.

Sp. 4. Fluat of lime.

Fluor.

This mineral is found abundantly in different countries, particularly in Derbyshire. It is both amorphous and crystallized.

Crystals.

The primitive form of its crystals is the regular octahedron; that of its integrant molecules the regular tetrahedron *. The varieties of its crystals hitherto observed amount to 7. These are the primitive octahedron; the cube; the rhomboidal dodecahedron; the cubo-octahedron, which has both the faces of the cube and of the octahedron; the octahedron wanting the edges; the cube wanting the edges, and either one face, or two faces in place of each. For a description and figure of these, the reader is referred to Mr Hauy †.

Properties.

The texture of fluat of lime is foliated. Lustre from 2 to 3, sometimes 0. Transparency from 2 to 4, sometimes 1. Causes single refraction. Hardness 8. Very brittle. Specific gravity from 3.0943 to 3.1911. Colours numerous, red, violet, green, red, yellow, blackish purple. Its powder thrown upon hot coals emits a bluish or greenish light. Two pieces of it rubbed in the

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* Hauy, *Jour de Min.* No. xxviii. 325.

† Ibid.

dark phosphoresce. It decrepitates when heated. Before the blow-pipe it melts into a transparent glass[*].

It admits of a polish, and is often formed into vases and other ornaments.

Sp. 5. Borat of lime.

Boracite.

Crystals.

This mineral has been found at Kalkberg near Luneburg, seated in a bed of sulphat of lime. It is crystallized. The primitive form of its crystals is the cube[†]. In general, all the edges and angles of the cube are truncated; sometimes, however, only the alternate angles are truncated[‡]. The size of the crystals does not exceed half an inch.

Properties.

The texture of this mineral is compact. Its fracture is flat conchoidal. External lustre 3; internal, greasy, 2. Transparency from 2 to 3. Hardness 9 to 10. Specific gravity 2.566. Colour greyish white, sometimes passing into greenish white or purplish.

When heated it becomes electric; and the angles of the cube are alternately positive and negative[§].

Before the blow-pipe it froths, emits a greenish light, and is converted into a yellowish enamel, garnished with small points, which, if the heat be continued, dart out in sparks[‖].

According to Westrum, who discovered its component parts, it contains

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[*] Hauy, *Jour. de Min.* No. xxviii. 325.

[†] Hauy, Ibid.

[‡] Hauy and Westrum.

[§] Hauy, Ibid. and *Ann. de Chim.* ix. 59.

[‖] Le Lievre, *Jour. de Min.* Ibid.

Class I.
Order II.

Composition.

68	boracic acid
13.5	magnesia
11	lime
1	alumina
2	silica
1	iron
96.5*	

Sp. 6. Arseniat of lime.

Pharmacolite of Kirsten.

Found in the Furstemberg of Wittichen in tubercles or small capillary crystals united in bundles. Colour snow white. Lustre silky. Texture fibrous; fibres diverging. Transparency of the crystals 4. Very friable. Klaproth found it composed of lime, arsenic acid, and a little cobalt.

Sp. 7. Nitrat of lime.

Found abundantly mixed with native nitre. For a description see Volume II. p. 300.

GENUS II. BARYTIC SALTS.

This genus comprehends the combinations of barytes with acids.

Sp. 1. Carbonat of barytes.

Witherite.

This mineral was discovered by Dr Withering; hence Werner has given it the name of *witherite.* It is found both amorphous and crystallized. The crystals are octahedrons or dodecahedrons, consisting of four or six sided pyramids applied base to base; sometimes the six-sided pyramids are separated by a prism; sometimes

Crystals.

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* *Ann. de Chim.* ii 116.

several of these prisms are joined together in the form of a star.

Properties.

Its texture is fibrous. Its fracture conchoidal. Its fragments long splintery. Lustre 2. Transparency 2 to 3. Hardness 5 to 6. Brittle. Specific gravity 4.3 to 4.338. Colour greenish white. When heated it becomes opaque. Its powder phosphoresces when thrown on burning coals *.

It is soluble with effervescence in muriatic acid. The solution is colourless.

Composition.

According to Pelletier it contains

62 barytes
22 carbonic acid
16 water

100†

Sp. 2. Sulphat of barytes.

Boroselenite.

This mineral is found abundantly in many countries, particularly in Britain. It is sometimes in powder, often in amorphous masses, and often crystallized. The primitive form of its crystals is a rectangular prism, whose bases are rhombs, with angles of 101° 30′ and 78° 30′‡. The varieties of its crystals are very numerous. For a description and figure of them I refer to Romé de Lisle § and Hauy ||. The most common varieties are the octahedron with cuneiform summits, the six or four sided prism, the hexangular table with bevelled edges. Sometimes these crystals are needleform.

Crystals.

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* Hauy.

† *Jour. de Min.* xxi. 46.

‡ Hauy, *Essai d'une Theorie*, p. 119.

§ *Crystal.* i. 583.

|| Ibid. and *Ann. de Chim.* xii. 3.

Class I. Order II. Properties.

Its texture is commonly foliated. Lustre from 0 to 2. Transparency from 2 to 0; in some cases 3 or 4. Hardness from 5 to 6. Specific gravity from 4.4 to 4.44. Colour commonly white, with a shade of yellow, red, blue, or brown.

When heated it decrepitates. It is fusible *per se* by the blue flame of the blow-pipe, and is converted into sulphuret of barytes. Soluble in no acid except the sulphuric; and precipitated from it by water.

Varieties.

Variety 1. Foliated sulphat.—Lustre 3 to 2. Transparency from 4 to 2, sometimes 1. Colours white, reddish, bluish, yellowish, blackish, greenish. Mr Werner subdivides this variety into three, according to the nature of the texture. These three subdivisions are *granularly foliated*, *straight foliated*, *curve foliated*.

Variety 2. Fibrous sulphat.—Texture fibrous; fibres converging to a common centre. Lustre silky or waxy, 2. Transparency 2 to 1. Hardness 5. Colours yellowish, bluish, reddish.

Variety 3. Compact sulphat.—Texture compact. Lustre 0 to 1. Transparency 1 to 0. Feels meagre. Almost constantly impure. Colours light yellow, red, or blue.

Variety 4. Earthy sulphat.—In the form of coarse dusty particles, slightly cohering. Colour reddish or yellowish white.

GENUS III. STRONTIAN SALTS.

This genus comprehends all the combinations of strontian and acids which form a part of the mineral kingdom.

Sp. 1. Carbonat of Strontian.

This mineral was first discovered in the lead mine of

Genus III. Species II.

Strontian in Argyleshire; and since that time it is said o have been discovered, though not in great abundance, n other countries. It is found amorphous, and also crystallized in needles, which, according to Hauy, are regular six-sided prisms.

Properties.

Its texture is fibrous; the fibres converge. Fracture uneven. Lustre 2. Transparency 2. Hardness 5. Specific gravity from 3.4 to 3.66. Colour light green. Does not decrepitate when heated. Before the blowpipe becomes opaque and white, but does not melt. With borax it effervesces, and melts into a transparent colourless glass. Effervesces with muriatic acid, and is totally dissolved. The solution tinges flame purple.

Sp. 2. Sulphat of strontian.

Celestine.

This mineral has been found in Pennsylvania, in Germany, in France, in Sicily, and Britain. It was first discovered near Bristol by Mr Clayfield. There it is found in such abundance, that it has been employed in mending the roads.

Properties.

It occurs both amphorous and crystallized. The crystals are most commonly bevelled tables, sometimes rhomboidal cubes. Its texture is foliated. More or less transparent. Hardness 5. Specific gravity from 3.51 to 3.96. Colour most commonly a fine sky blue; sometimes reddish; sometimes white, or nearly colourless *.

Composition.

Klaproth found a specimen of this mineral from Pennsylvania composed of 58 strontian
42 sulphuric acid

100 †

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* Clayfield, Nicholson's *Jour.* iii. 36.

† Beitrage, ii. 97.

Class I.
Order II.

According to the analysis of Mr Clayfield, the sulphat of strontian found near Bristol is composed of

58.25 strontian
41.75 sulphuric acid of 2.24, and a little iron *.

100.00

According to the analysis of Vauquelin, the sulphat of strontian found at Bouvron in France, which was contaminated with .1 of carbonat of lime, is composed of . . . . 54 strontian
45 sulphuric acid

99 †

GENUS IV. MAGNESIAN SALTS.

Sp. 1. Sulphat of magnesia.
Sp. 2. Nitrat of magnesia.

These salts are found in different countries, either sparingly mixed with the soil, or efflorescing upon walls, or dissolved in mineral waters. I have mentioned them merely in compliance with the custom of mineralogists: for they ought not, strictly speaking, to be ranked among minerals. For a description of them, I refer to the First Part of this Work ‡.

GENUS V. ALUMINOUS SALTS.

This genus comprehends all the combinations of alumina with acids, which consitute a part of the mineral kingdom. Hitherto only three species have occurred.

Sp. 1. Alum.

This salt is found in crystals, in soft masses, in flakes,

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* Clayfield, Nicholson's *Jour.*

† *Jour de Min.* No. xxxvii. 6.

‡ See vol. ii. p. 267. and 305.

Genus V.
Species II.

and invisibly mixed with the soil. For a description, I refer to Vol. II. p. 272.

Sp. 2. Mellite *.

Honeystone—Mellat of Alumina.

Properties

This mineral was first observed about ten years ago in Thuringia, between the layers of wood-coal. It is of a honey-yellow colour (hence its name), and is usually crystallized in small octahedrons, whose angles are often truncated. Lustre 2 to 3. Transparency considerable. Fracture conchoidal. Hardness 5. Specific gravity, according to Abich, 1.666. When heated it whitens; and in the open air burns without being sensibly charred. A white matter remains, which effervesces slightly with acids, and which at first has no taste, but at length leaves an acid impression upon the tongue.

Analysis.

Abich shewed that it is composed chiefly of alumina and an acid which exhibited some of the properties of the benzoic. This analysis was repeated by Klaproth, who found the mellite composed of alumina and a peculiar acid to which he gave the name of *mellitic acid*. Vauquelin obtained the same result. The mellitic acid has several properties in common with the oxalic, which induced him at first to consider it as the same with that acid. But Klaproth has since demonstrated that it is different.

Mellitic acid.

The *mellitic* acid, when exposed to heat, is decomposed very speedily, and evaporates in a thick grey smoke. When distilled it yields a great quantity of carbonic acid. It combines in excess with potass, and forms a super-mellat, which has a slightly acid taste, is sparingly

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* Emmerling's *Lehrbuch*, ii. 89.—Wiedeman's Hanbuch, p. 639.—Abich, Crell's *Annals*, 1797, ii. 3.—Vauquelin, *Ann. de Chim.* xxxvi. 23.—Klaproth, Ibid. xxxvii. 88.—Kirwan's *Min.* ii. 68. Karsten, *Mus. Leck.* ii. 335.

soluble in water, and crystallizes. When this salt is poured into a solution of sulphat of alumina, it occasions a flaky precipitate; whereas super-oxalat of potass occasions none.

Sp. 3. Chriolite *.

Sulphat of soda-and-alumina.

Properties.

This mineral has hitherto been found in Greenland only; from which it was brought to Copenhagen, where it lay eight or nine years unnoticed, till at last it was analysed by Abelgaard. The primitive form of its crystals seems to be an octahedron, whose faces are isosceles triangles. Its colour is snow white. Texture foliated. Hardness inferior to that of fluat of lime. Specific gravity 2.949. Melts before it reaches a red heat, and when simply exposed to the flame of a candle †. Abelgaard analysed it, and obtained fluoric acid and alumina. Klaproth has lately proved that it contains also soda. The result of his analysis is as follows:

Composition.

40.5 fluoric acid and water
36.0 soda
23.5 alumina

100.0

This analysis has been confirmed by Vauquelin.

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[*] *Ann. de Chim.* xxxvii. 87. and 89.—*Jour. de Phys.* lii. 35.—Hauy, Ibid. xlix. 462.

[†] Hence its name from κρυος and λιθος, as if it melted as easily as ice.

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END OF THE THIRD VOLUME.

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Plate III.

CHEMISTRY

End of Vol. III.

Fig. 16.

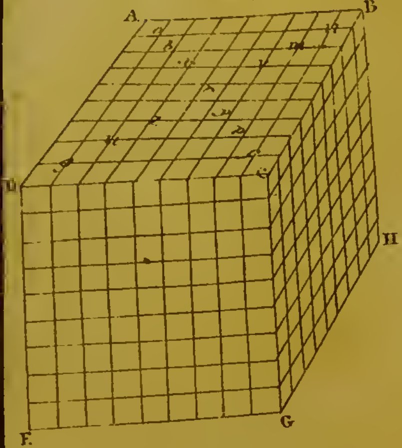

Fig. 17.

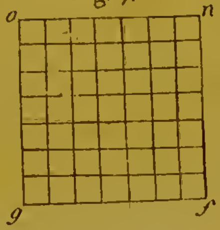

Fig. 18.

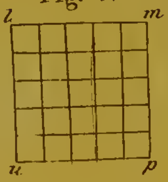

Fig. 19.

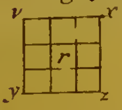

Fig. 20.

Fig. 21.

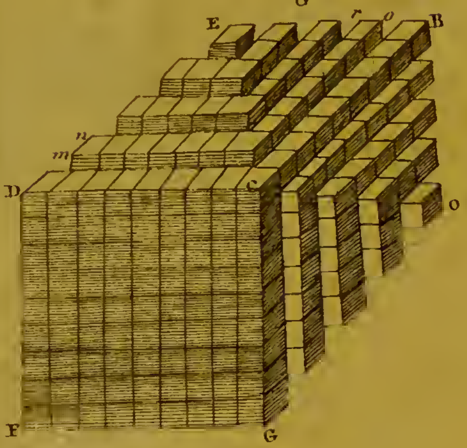

Fig. 22.

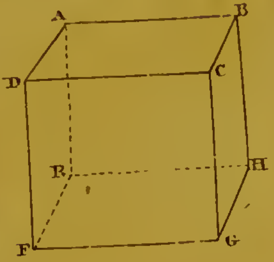

Fig. 23.

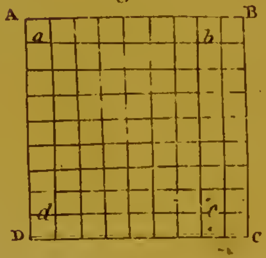

Fig. 24.

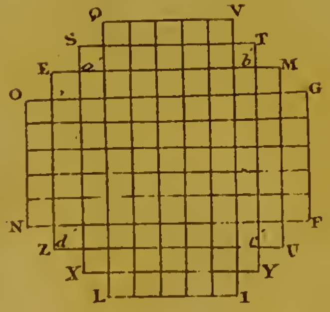

Fig. 25.