A
SYSTEM
OF
CHEMISTRY.

IN FIVE VOLUMES.

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PART II.

CHEMICAL EXAMINATION
OF NATURE.

Having, in the First Part of this Work, given a very full detail of the principles of Chemistry, and a description of the different Substances with which it is necessary for the Chemist to be acquainted, I propose, in this Second Part, to take a view of the different substances as they exist in nature, constituting the material world, that we may ascertain how far the science of chemistry will contribute towards explaining their nature, and accounting for the different changes which they produce on each other. Now the different substances of which the material world, as far as we have access to it, is composed, may be very conveniently arranged under the five following heads:

1. The Atmosphere,
2. Waters,
3. Minerals,
4. Vegetables,
5. Animals.

These five divisions will form the subject of the five following Books.

BOOK I.

OF THE

ATMOSPHERE.

Book I.

The atmosphere is that invisible elastic fluid which surrounds the earth to an unknown height, and encloses 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 atmosphere seem to have occupied much of the attention of the antients. Aristotle considered it as one of the four elements, situated between the regions of *water* and *fire*, and mingled with two *exhalations*, the *dry* and the *moist;* the first of which occasioned thunder, lightning, and wind; while the second produced rain, snow, and hail. The ancients, in general, seem to have considered the blue colour of the sky as essential to the atmosphere; and several of their philosophers believed that it was the constituent principle of other bodies, or at least that air and other bodies are mutually convertible into each other *. But these opinions continued in the state of vague conjectures, till the matter was explained by the sagacity of Hales, and of those philosophers 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 dilatability; 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,

1. Air, 3. Carbonic acid gas,
2. Water, 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 barometical 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 $\frac{4\pi(R+r)^3}{3} - \frac{4\pi R^3}{3} = 4\pi\left(R^2 r + r^2 R + \frac{r^3}{3}\right)$, 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 the solidity of the hollow sphere of mercury in cubic feet. But a cubic foot of mercury is nearly equal to 13,5000 avoirdupois ounces. Hence the mean weight of the atmosphere amounts to about 1,911,163,227,258,181,818 lbs. avoirdupois.

SECT. I.

OF AIR.

Air an elastic fluid.

THE word AIR seems to have been used at first to denote 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 are 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 various species of them. In consequence of this discovery, the word *air* became generic, and was applied by Priestley, and the British and Swedish philosophers in general, to all permanently elastic fluids, while the air of the atmosphere was distinguished by the epithets of *common* or *atmospheric* air: but Macquer thought proper to apply the term *gas*, first employed by Van Helmont, to all permanently elastic fluids except common air, and to confine the term *air* to this last fluid. This innovation was scarcely necessary; but as it has now been generally adopted, it will be proper to follow it. By the word *air*, then, in this Section, I mean only common *air*, or the fluid which forms by far the greatest part of the atmosphere.

The foreign bodies which are mixed or united with air in the atmosphere are so minute in quantity compared to it, that they have no very sensible influence on its properties. We may therefore consider atmospheric air, when in its usual state of dryness, as sufficiently pure for examination.

Specific gravity.

1. Air is an elastic fluid, invisible indeed, but easily recognized by its properties. Its specific gravity, according to the experiments of Sir George Shuckburgh, when the barometer is at 30 inches, and the thermometer between 50° and 60°, is usually reckoned 1·000: It is 816 times lighter than water. One hundred cubic inches of air weigh 31 grains troy.

Density.

But as air is an elastic fluid, and compressed at the surface of the earth by the whole weight of the incumbent atmosphere, its density diminishes according to its height above the surface of the earth. From the experiments of Paschal, Deluc, General Roy, &c. it has been ascertained, that the density diminishes in the ratio 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 †.

Colour.

2. 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 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 instrument consisted of a circular band of paper, divided into 51 parts, each of which was painted with a different shade of blue; beginning with the deepest mixed with black, to the lightest mixed with white. He found that the colour of the sky always corresponds with a deeper shade of blue the higher the observer is placed above the surface; consequently, at a certain height, the blue will disappear altogether, and the sky appear black; that is to say, will reflect no light at all. The colour becomes always lighter in proportion to the vapours mixed with the air. Hence it is evidently owing to them ‡.

Composition.

3. For many ages air was considered as an element

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* *Mem. Par.* 1753. p. 515.

† *Jour. de Phys.* xxxvi. 98.

‡ Saussure, *Voyages dans les Alpes*, iv. 288.

or simple substance. For the knowledge of its component parts, we are indebted to the labours of those philosophers in whose hands chemistry advanced with such rapidity during the last forty years of the 18th century. The first step was made by Dr Priestley in 1774, by the discovery of oxygen gas. This gas, according to the prevailing theory of the time, he considered as air totally deprived of phlogiston; azotic gas, on the other hand, was air saturated with phlogiston. Hence he considered common air as oxygen gas combined with an indefinite portion of phlogiston, varying in purity according to that portion; being always the purer the smaller a quantity of phlogiston it contained.

While Dr Priestley was making experiments on oxygen gas, Scheele proceeded to the analysis of air in a different manner. He observed that the liquid sulphurets, phosphorus, and various other bodies, when confined along with air, have the property of diminishing its bulk; and this diminution always amounts to a certain proportion, which he found to be between a third and a fourth part of the whole. The residuum was unfit for supporting flame, and was not diminished by any of the processes which diminish common air. To this residuum he gave the name of *foul air*. From these experiments, he concluded that air is a compound of two different elastic fluids: namely, *foul air*, which constitutes more than two thirds of the whole, and *another air*, which is alone capable of supporting flame and animal life. This last air he extricated from nitre by heat, from the black oxide of manganese, and from other substances, and gave it the name of *empyreal air*. He showed that a mixture of two parts of foul air and one part of empyreal air possesses the properties of common air *.

The foul air of Scheele was the same with the phlogisticated air of Priestley, or with what is now known by the name of *azotic gas*. His empyreal air is the same with the dephlogisticated air of Priestley, or with what is at present called *oxygen gas*. According to him, therefore, air is a compound of two parts of azotic and one part of oxygen gas. He accounted for the diminution of air by the liquid sulphurets and other similar bodies by his theory of the composition of caloric, which he considered as a compound of phlogiston and oxygen gas. According to him, the phlogiston of the sulphuret combines with the oxygen of the air, and passes through the vessels in the state of caloric, while the azotic gas, which has no affinity for caloric, is left behind.

While Scheele was occupied with his experiments on air, Lavoisier was assiduously employed on the same subject, and was led by a different road to precisely the same conclusion as Scheele. By oxidizing mercury in a vessel filled with common air, and heated to the boiling point of mercury, he abstracted the greater part of its oxygen gas; and by heating the red oxide thus formed, he reconverted it into mercury, while at the same time a quantity of oxygen gas was extricated. The residuum in the first experiment possessed the properties of azotic gas; but when the oxygen gas extricated from the mercury was added to it, the mixture assumed again the properties of common air. Hence he concluded

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* Scheele on *Air and Fire*, p. 7. &c. Engl. Transl.

that air is composed of azotic gas and oxygen; and from a variety of experiments he determined the proportions to be 73 parts of azotic gas and 27 parts of oxygen gas. He demonstrated, too, that when air is diminished by liquid sulphurets, metals, &c. the oxygen gas which is abstracted combines with the sulphurets, &c. and converts them into acids or oxides according to their respective nature. But as all these experiments have been already detailed in the First Part of this Work, it is unnecessary to be more particular in this place.

Air composed of oxygen and azotic gas.

Air, then, is a compound of oxygen and azotic gas: but it becomes a question of considerable consequence to determine the proportion of these two ingredients, and to ascertain whether that proportion is in every case the same. Since azotic gas, one of the component parts of that fluid, cannot be separated by any substance with which chemists are acquainted, the analysis of air can only be attempted by exposing it to the action of those bodies which have the property of absorbing its oxygen. 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 being once known, it is easy to ascertain the proportion of azotic gas, and thus to determine the exact relative quantity of the component parts of air.

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 at different times and in different places; and that upon this variation depended the purity or noxious qualities of air. Hence it became an object of the greatest importance to get possession of a method to determine readily the quantity of oxygen in a given portion of air. Accordingly various methods were proposed, all of them depending upon the property which many bodies possess, of absorbing the oxygen of the air without acting upon its azote. 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 measures 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 Priestely'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 evident, that in all cases of a mixture of these two gases the diminution will be proportional to the quantity of the oxygen. Of course it will indicate the proportion of oxygen in air; and by mixing it with different portions of air, will indicate the different quantities of oxygen which they contain, provided the component parts of air be susceptible of variation. Dr Priestley's method was to mix together equal bulks of air and nitrous gas in a low jar, and to transfer the mixture into a narrow graduated glass tube about three 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 mixed toge.

ther equal parts of nitrous gas and air, the sum total of this mixture was 200 (or 2·00): suppose the residuum when measured in the graduated tube to amount to 104 (or 1·04), and of course that 96 parts of the whole had disappeared, he denoted the purity of the air thus tried by 104. A more convenient instrument was invented by Dr Falconer of Bath; and Fontana greatly improved this method of measuring the purity of air. A description of his eudiometer was published by Ingenhousz in the first volume of his Experiments; but it was Mr Cavendish who first brought this eudiometer to such a state of precision as to be enabled to ascertain correctly the constituents of air. His method was to put 125 measures of nitrous gas into a glass vessel, and to let up into it very slowly 100 measures of the air to be examined, agitating the vessel containing the nitrous gas during the whole time. The diminution of bulk when the process was conducted in this way was almost uniform. The greatest was 110, the least 106·8; the mean 108·2. The variation he found to depend, not upon the air examined, but upon the state of the water in which the experiment was made. If the experiment was reversed, by letting up the nitrous gas to common air, he used 100 measures of each, and the diminution in that case was only 90 measures.

Improved by Cavendish.

This constancy in the diminution of the bulk of all the different specimens of common air examined, induced Mr Cavendish to conclude that the proportion between the oxygen and azote in common air does not vary. To find the absolute quantity of oxygen in air, he mixed together oxygen gas and azote in various proportions, and at last found that a mixture of 10 measures of the purest oxygen which he could procure with

38 measures of azote, was just as much diminished by nitrous gas as the same bulk of common air. Hence he concluded that air is composed of 10 parts by bulk of oxygen and 38 of azote, which gives us for its composition *per cent.*

79·16 azote
20·84 oxygen

100·00

or very nearly 21 *per cent.* of oxygen gas *.

Dalton's method.

Other philosophers, who did not pay that rigid attention to precision which characterises all Mr Cavendish's experiments, obtained variable results from the nitrous gas eudiometer. Most of the circumstances which occasion the variation were pointed out by Cavendish; but they seem to have escaped the observation of succeeding chemists. Humboldt's attempt to render the eudiometer of Fontana accurate did not succeed †. But Mr Dalton has lately explained the anomalies in a very luminous manner. According to this philosopher, oxygen gas and nitrous gas are capable of uniting in two proportions: 21 measures of oxygen gas uniting either with 36 measures of nitrous gas, or with twice 36, = 72 measures. Both of these compounds are soluble in water. If the tube be wide, a considerable portion of nitrous gas comes at once in contact with the oxygen. Hence the latter gas combines with a maximum of nitrous, especially if agitation be employed. In a narrow tube the oxygen combines with the minimum of nitrous gas, provided no agitation be employed, and the residue

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* *Phil. Trans.* 1783, p. 107.

† *Ann.* xxvii. p.

be poured soon into another vessel. When intermediate proportions are used, the absorption will be intermediate. Mr Dalton recommends a narrow tube; the nitrous gas is to be only in the proportion requisite to form the minimum combination; no agitation is to be employed; and when the diminution is completed, the gas must be transferred to another tube. To 100 measures of air add about 36 of nitrous gas; note the diminution of bulk, and multiply it by $\frac{7}{19}$; the product gives the bulk of oxygen in the air examined *.

Davy's method.

In order to get rid of the anomalies which had perplexed former experimenters, Mr Davy proposed to employ the nitrous gas in a different state. He caused sulphate or muriate of iron to absorb this gas to saturation, and employed the dark brown liquid thus obtained to deprive air of its oxygen. A small graduated glass tube, filled with the air to be examined, is plunged into the nitrous solution, and moved a little backwards and forwards. The whole of the oxygen is absorbed in a few minutes. The state of greatest absorption ought to be marked, as the mixture afterwards emits a little gas, which would alter the result. By means of this, Mr Davy examined the air at Bristol, and found it always to contain about 0·21 of oxygen. Air sent to Dr Beddoes from the coast of Guinea gave exactly the same result.

Method of Scheele.

2. For the second 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 mix-

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* Dalton, *Phil. Mag.* xxiii. 351.

ture 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 upon the iron; but the hydrogureted sulphurets, formed by boiling together sulphur and liquid potash 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 effected 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 introduced into a glass bottle filled with liquid sulphuret of lime previously saturated with azotic gas, and capable of holding from two to four times the bulk of the air introduced. The bottle is then to be corked with a ground glass stopper, and agitated for five minutes. After this the cork is to be withdrawn while the mouth of the phial is under water; and for the greater security, it may be corked and agitated again. After this, the air is to be again transferred to the graduated glass tube, in order to ascertain the diminution of its bulk *.

Air examined by this process suffers precisely the same diminution in whatever circumstances the experiments are made: no variation is observed whether the wind be high or low, or from what quarter soever it blows; whether the air tried be moist or dry, hot or cold; whether the barometer be high or low. Neither the season of the year, nor the situation of the place, its vicinity to the sea, to marshes, or to mountains, make any difference. Mr De Marti found the diminution always between 0·21 and 0·23.

Eudiometer of Volta.

3. The third 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

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* *Jour. de Phys.* lii. 176.

judge of the purity of the air by the bulk of the residuum. This method has been lately examined by Gay Lussac and Humboldt. They have found it susceptible of great precision. It is one of the simplest and most elegant methods of estimating the proportion of oxygen in air. When 100 measures of hydrogen are mixed with 200, or any greater bulk of oxygen, up to 900 measures, the diminution of bulk after detonation is always 146 measures. The same diminution is obtained if the hydrogen be increased up to a certain quantity. The result of their trials is, that 100 measures of oxygen gas require 200 of hydrogen for complete combustion, which coincides very well with the trials previously made in this country. Hence the method of using this eudiometer is very simple: Mix together equal bulks of the air to be examined and of hydrogen gas, ascertain the diminution of bulk after combustion, divide it by three, the quotient represents the number of measures of oxygen in the air. A great number of trials, in different seasons of the year, of mixtures of 200 measures of air and as much hydrogen, gave almost uniformly a diminution of bulk amounting to 126 measures. Now the third of 126 is 42, the quantity of oxygen in 200 measures of air. Hence 100 parts of air, according to these trials, contain 21 of oxygen *.

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 ‡,

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* *Jour. de Phys.* lx. 129.

† Ibid. 1784, vol. i.

‡ *Ann. de Chim.* xiii. 38.

and by Seguin and Lavoisier *; but Berthollet † has lately brought it to a state of perfection.

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 the water. The residuum is merely the azotic gas of the air, holding a portion of phosphorus in solution. Berthollet has ascertained, that by this foreign body its bulk is increased $\frac{1}{40}$th part. Consequently the bulk of the residuum, diminished by $\frac{1}{40}$, gives us the bulk of the azotic gas of the air examined; which bulk, subtracted from the original mass of air, gives us the proportion of oxygen gas contained in it ‡.

All the different experiments which have been made by means of this eudiometer agree precisely in their

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* *Ann. de Chim.* ix. 293.

† Ibid. xxxiv. 73. and *Jour. de l'Ecole Polytechn.* I. iii. 274.

‡ A very convenient apparatus for making eudiometrical experiments, has lately been invented by Mr Pepys, and described by him in *Phil. Trans.* for 1807.

result, and indicate that the proportions of the ingredients of air are always the same; namely, about 0·21 parts of oxygen gas, and 0·79 of azotic gas. Berthollet found these proportions in Egypt and in France, and I have found them constantly in Edinburgh, in all the different seasons of the year.

Thus it appears, that whatever method is employed to abstract oxygen from air, the result is uniform, provided the experiment be precisely made. They all indicate that common air consists very nearly of 21 parts of oxygen and 79 of azote. Scheele and Lavoisier found 27 *per cent.* of oxygen, but their methods were not susceptible of precision. Air, then, does not vary in its composition; the proportion between its constituents is constant in all places and in all heights. Gay Lussac examined air brought from the height of more than 21,000 feet above Paris, and found it precisely the same as the air at the earth's surface *.

Constituents of air.

But 21 cubic inches of oxygen gas weigh 7·14 grains, and 79 inches of azote weigh 23·9686 grains. These added together amount to 31·1086 grains, which ought to be the weight of 100 inches of common air. But this is somewhat greater than the weight of 100 inches of air, according to Sir John Shuckburgh Evelyn's experiments, who found it only 31·0197 grains. The difference is not great, and is probably owing to a small error in the specific gravities of the different gases. According to this estimate, 100 parts of air are composed by weight of

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* *Phil. Mag.* xxi. 225.

Chap. I.

22·91 oxygen
77·09 azote

100·00

Method of ascertaining the density of the air operated on.

In all the analyses of 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 dependence 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.

It has been ascertained by philosophers, that the volumes of air are always inversely as the compressing forces. Therefore let m be the height of the barometer at the commencement of an experiment, n its height at the end, v the volume of the gas when the barometer is at n, and x its volume, supposing the barometer at m. We have $n : m :: x : v$. Consequently $x = \frac{n\,v}{m}$. So that to find the volume required, we have only to multiply the volume obtained by the actual height of the barometer, and divide by the height of the barometer at which we want to know the volume: And, in general, to reduce a volume of air to the volume it would occupy, supposing the barometer at 30 inches, we have only to use the above formula, substituting 30 in place of m.

To reduce it to the density of external air.

2. When air is confined in a jar standing over water or mercury, its density is not the same with that of the atmosphere, unless its lower surface in the jar be exactly level with the surface of the liquid in the tub in which it stands. Let A (fig. 39.) be a jar containing air, and BC the surface of the water or mercury in the tub in which the jar is inverted; the air within the jar is not of the same density with the external air, unless it fills exactly that part of the jar above BC. If it fill only that part of it between A and D, while the water or mercury rises to D, the air will be more dilated than the external air, because it is compressed only by the weight of the atmosphere, diminished by the column of mercury or water D m. On the other hand, if the water or mercury only rise in the jar to E, the air within it will be denser than the external, because it is compressed 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 or 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, b 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 $H : H - b :: v : x$. And $x = \frac{(H - b)v}{H}$. Thus let H be 30 inches, $b = 5$ 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 over water is only $2\frac{1}{2}$ inches, or the 80th part of the whole.

Allowance for temperature.

3. A change in the temperature may be more easily guarded against in eudiometrical experiments, as they are usually made within doors: but when it does happen, it occasions an alteration in the volume of the air; an increase of temperature dilating it, and a diminution of temperature occasioning a condensation. This error may be easily corrected in air and all other gases, by increasing or diminishing their apparent bulk for every degree of change in the thermometer, according to the Table of the dilations of the gases formerly given *.

Mr Dalton considers air as merely a mechanical mixture of the two gases of which it is composed. But all other chemists consider it as a chemical compound. This subject has been discussed in a preceding part of this Work. I consider it as composed of azote and oxygen holding each other in *dissolution* †.

SECT. II.

OF WATER.

Water of the atmosphere.

THAT the atmosphere contains water has been always known. The rain and dew which so often precipitate from it, the clouds and fogs with which it is often obscured, and which deposite moisture on all bodies exposed to them, have demonstrated its existence in every age. Even when the atmosphere is perfectly transparent, water may be extracted from it in abundance

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* See Vol. I. p. 495.

† See Vol. p. III. 457

by certain substances. Thus, if concentrated sulphuric acid be exposed to air, it gradually attracts so much 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, muriate of lime, nitrate 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 measures 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.

Detected by the hygrometer.

Since it cannot be doubted that the atmosphere always contains water, there are only two points which remain to be investigated: 1. The state in which that water exists in air; 2. The quantity which a given bulk contains.

State in which water exists in air.

I. With respect to the state in which water exists in air, two opinions have been formed, each of which has been supported by very able philosophers. 1. Water may be dissolved in air in the same manner as a salt is held in solution by water. 2. It may be mixed with air in the state of steam or vapour, after having been converted into vapour.

1. The first of these opinions was hinted at by Dr Hooke in his *Micrographia*, and afterwards proposed by 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, has been embraced by Deluc in his last treatise on Meteorology; at least his reasoning appears to me to lead to that conclusion. But it is to Mr Dalton that we are indebted for the most precise information on the subject*. The following reasons

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* *Manchester Memoirs*, v. p. 571.

put the truth of this opinion almost beyond the reach of controversy.

It is in the state of vapour.

In the *first* place, It cannot be doubted that the water which exists in air, is derived originally from the waters on the surface of the earth, which are exposed to the action of the atmosphere. Accordingly we find that water, when exposed to the air, suffers a gradual diminution of bulk, and at last disappears altogether. This diminution of the water may be owing, either to its gradual solution in air, or to its conversion into vapour. The last is the common opinion, as the phenomenon is in common language ascribed to the *evaporation* of the water. When water is placed in an exhausted receiver, it diminishes in bulk even more rapidly than in the open air. In this case, as no air is present, we can only ascribe the diminution of bulk to the conversion of the water into vapour. Accordingly we find, upon examination, that the receiver is actually filled with water in the state of vapour. The presence of this vapour very soon, by its elasticity, puts an end to the evaporation of the water. Now, since water disappears equally whether air be present or not, and exactly in the same manner, it is reasonable to ascribe its disappearing in both cases to the same cause. But in the exhausted receiver it is converted into vapour. Hence it is probable that it is converted into vapour also in the open air; and if so, it must exist in air in the state of vapour.

In the *second* place, If the disappearing of water exposed to the open air were owing to solution and not to evaporation, it ought certainly to disappear more rapidly when it is exposed to the action of a great quantity of air than when to a small quantity; for the quantity of any body dissolved is always proportional to the quantity of the solvent. But the very contrary is what actually 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 the 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

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[*] Saussure's *Voyages dans les Alpes*, iv. 263.

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 disappears carries off with it a quantity of caloric. It is well known, that when a wet body is exposed to the air, its temperature is lowered by the evaporation which takes place upon its surface. Hence, in warm countries water is cooled by putting it into porous vessels, and exposing it to the air. The water penetrates through the vessels, evaporates from their surface, and carries off so much heat, as even in some cases to freeze the water in the vessel. Saussure observed, that the evaporation from the surface of melting snow caused it to freeze again when the temperature of the surrounding air was 4·5° above the freezing point. Dr Black has rendered it probable that the quantity of caloric which disappears during spontaneous evaporation, is as great as that which is necessary to convert water into steam. We have a right then to conclude, that water, when it evaporates spontaneously, is always converted into vapour, and of course that it is only in that state that it enters into the atmosphere.

In the *fourth* place, Mr Dalton has demonstrated, that the water which exists in air, possesses precisely the same degree of elasticity that it does when in the state of a vapour in a vacuum at the same temperature. Hence it follows irresistibly that it exists in air, not in the state of water, but of an elastic fluid or vapour.

We are authorised to conclude, then, that the water which exists in the atmosphere is in the state of vapour. This vapour is held in solution by the air precisely as one species of gas is by another. Hence the reason why it is so difficult to separate it, and why it is capable of undergoing a considerable degree of compression without assuming the form of a liquid *.

Quantity of vapour in air.

II. Many attempts had been made to measure the quantity of water contained in air; but Saussure was the first who attained any thing like precision. This ingenious philosopher has shown, in his Hygrometrical Essays, that an English cubic foot of air, when saturated with water, at the temperature of 66°, contains only about eight grains troy of that liquid, or about $\frac{1}{67}$th of its weight. But the experiments of Mr Dalton were susceptible of more precision. As the greatest part of the water of the atmosphere is in the state of vapour, the elasticity of which depends upon the temperature, it is obvious that this elasticity, provided it can be ascertained, must measure the quantity of vapour which exists in the atmosphere, the temperature being the same. The elasticity or force of vapour was determined by this ingenious philosopher in the following manner, which had been originally contrived by Le Roy: He took a tall cylindrical glass jar, dry on the outside, and filled it with cold spring water fresh from the well: if dew was immediately formed on the outside, he poured the water out, let it stand a while to increase in temperature, dried the outside of the glass well with a linen cloth, and then poured the water in again. This operation was to be continued till the dew ceased to be formed, and then the temperature of the water was observed; and opposite to it in the Table † was found the force of vapour in the atmosphere. This experiment must be conducted in the open air, or at a window; be-

Dalton's method of ascertaining its elasticity.

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* See Vol. III. p. 462.

† Ibid. I. p. 537.

cause the air within is generally more humid than that without. Spring water is generally about 50°, and will mostly answer the purpose of the three hottest months in the year: in other seasons an artificial cold mixture is required.

From Dalton's experiments it follows that the quantity of vapour in the atmosphere is variable in quantity. In the torrid zone its force varies from 0·6 to one inch of mercury. In Britain it seldom amounts to 0·6, but is often as great as 0·5 during summer. In winter it is often as low as 0·1 of an inch of mercury *.

These facts would enable us to ascertain the absolute quantity of vapour contained in the atmosphere at any given time, provided we were certain that the density and elasticity of vapours follow precisely the same law as that of gases, as is extremely likely to be the case. If so, the vapour will vary from $\frac{1}{60}$th to $\frac{1}{300}$th part of the atmosphere. Dalton supposes that the medium quantity of vapour held in solution at once in the atmosphere may amount to about $\frac{1}{70}$th of its bulk †.

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 pe-

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* Dalton, *Manchester Memoirs*, v. 547.

† *Phil. Mag.* xxiii. 353.

culiar fluid. If we expose a pure alkali or alkaline earth to the atmosphere, it is gradually converted into a carbonate 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 carbonate had been ascertained to depend upon that acid. Not only alkalies and alkaline earths 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 carbonates. Thus *rust* is always saturated with 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 potash, acquired the property of effervescing 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. Humboldt 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,

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* Saussure's *Voyages*, iv. 199.

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.

Its quantity.

The difficulty of separating this gas from air has rendered it difficult to determine with accuracy the relative quantity of it in a given bulk of air. From the experiments of Humboldt, it appears to vary from 0·005 to 0·01.

Mr Dalton's experiments give the quantity much smaller. He found, that if a glass vessel filled with 102,400 grains of rain water be emptied in the open air, and 125 grains of lime water be poured in, and the mouth then closed; by sufficient time and agitation, the whole of the lime water is just saturated with the carbonic acid which it finds in the inclosed volume of air: but 125 measures of lime-water require 70 measures of carbonic acid gas to saturate them. Hence he concludes, that air contains only $\frac{1}{1400}$th of its bulk of carbonic acid †.

From the previous experiments of Mr Cavendish, however, we learn that lime water is not capable of depriving air of the whole of its carbonic acid. A portion still remains, which can only be separated either by milk of lime, or by repeated washings with new doses of lime-water. Hence the quantity of carbonic acid in air must be considerably greater than it was found by Dalton. I do not know exactly the meaning of *lime-water being just saturated,* unless it signifies that it refuses to absorb any more gas. In that case the whole

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* *Jour. de Phys.* xlvii. 202.

† *Phil. Mag.* xxiii. 354.

of the lime is held in solution by the acid. It must be difficult to ascertain the exact point of saturation according to this sense of the word. We may conclude, however, from Dalton's experiment, that the bulk of carbonic acid in air does not much exceed $\frac{1}{1000}$th of the atmosphere; but it is liable to variation from different circumstances. Immense quantities of carbonic acid 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 the gas 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 is formed.

SECT. IV.

OF THE OTHER BODIES FOUND IN THE ATMOSPHERE.

Composition of the atmosphere.

FROM the three preceding Sections, we see that the atmosphere consists chiefly of three distinct elastic fluids united together by chemical affinity; namely, air, vapour, and carbonic acid gas; differing in their proportions at different times and in different places; but that the average proportion of each is

98·9 air
1·0 vapour
0·1 carbonic acid

100·0

Other bodies contained in it.

But besides these bodies, which may be considered as the constituent parts of the atmosphere, the existence of several other bodies has been suspected in it. I do not mean in this place to include among those bodies electric matter, or the substance of clouds and fogs, and those other bodies which are considered as the active agents in the phenomena of meteorology, but to confine myself merely to those foreign bodies which have been occasionally found or suspected in air. Concerning these bodies, however, very little satisfactory is known at present, as we are not in possession of instruments sufficiently delicate to ascertain their presence. We can indeed detect several of them actually mixing with air, but what becomes of them afterwards we are unable to say.

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. From the experiments of Gay Lussac and Humboldt, it appears that air does not contain so much as $\frac{3}{1000}$th parts hydrogen.

2. Carbureted 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 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, keeps its component parts always at 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 body, have attracted a great deal of attention. These are known by the names of matters of *contagion*.

That there is a difference between the atmosphere in different places, as far as respects its effects upon the human body, has been considered as an established point in all ages. Hence some places have been celebrated as healthy, and others avoided as pernicious to the human constitution. It is well known that in pits and mines the air is often in such a state as to suffocate almost instantaneously those who attempt to breathe it. Some places are haunted by peculiar diseases. It is known that those who frequent the apartments of persons ill of certain maladies, are extremely apt to catch the infection; and in prisons and other places, where crowds of people are confined together, when diseases once commence, they are wont to make dreadful havoc. In all these cases, it has been supposed that a certain noxious matter is dissolved by the air, and that it is the action of this matter which produces the mischief.

Contagious matter,

This noxious matter is in many cases readily distinguished by the peculiarly disagreeable smell which it communicates to the air. No doubt this matter differs according to the diseases which it communicates, and the substance from which it has originated. Morveau lately attempted to ascertain its nature; but he soon found the chemical tests hitherto discovered altogether insufficient for that purpose. He has put it beyond a doubt, however, that the noxious matter which rises from putrid bodies is of a compound nature; and that it is destroyed altogether by certain agents, particularly by those gaseous bodies which readily part with their oxygen. He exposed air infected by putrid bodies to the action of various substances; 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 fe-

tid odour. 5. Sulphuric acid has no effect; sulphurous acid weakens the odour, but does not destroy it. 6. Vinegar 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 oxymuriatic acid gas, first proposed by Mr Cruikshanks, 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 may be attended with some inconvenience, because it is almost always contaminated with nitrous gas. Muriatic acid and oxymuriatic 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 common salt with one part of the black oxide of manganese, to place the mixture in an open vessel in the infected chamber, and to pour upon it two parts of sulphuric acid. The fumes of oxymuriatic acid are immediately exhaled, fill the chamber, and destroy the contagion. Or the oxymuriate of lime, sold for the purposes of the bleacher, may be mixed with sulphuric acid, and placed in the infected apartment.

CHAP. II.

OF METEOROLOGY.

Though the phenomena of the weather must have at all times attracted much of the attention of mankind, because their subsistence and their comfort in a great measure depended upon them, it was not till the 17th century that any considerable progress was made in investigating the laws of meteorology. How desirous soever the ancients might have been to acquire an accurate knowledge of this science, their want of proper instruments entirely precluded them from cultivating it. By the discovery of the barometer and thermometer in the 17th century, and the invention of accurate electrometers and hygrometers in the 18th, this defect is now pretty well supplied; and philosophers are enabled to make meteorological observations with ease and accuracy. Accordingly, a very great number of such observations have been collected, which have been arranged and examined from time to time by ingenious men, and consequences 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 changes in its quantity by evaporation and rain, &c.; 4. The violent agitation into which it is often thrown; and, 5. The electric and other phenomena which sometimes accompany or occasion these precipitations and agitations. The consideration of these subjects shall occupy the six following Sections.

SECT. I.

OF CHANGES IN THE WEIGHT OF THE ATMOSPHERE.

Height of the barometer on the sea shore.

We have seen in the last Chapter, that the barometer indicates to us the weight of a column of air extending to the top of the atmosphere, and whose base is equal to that of the mercury. At the level of the sea, where the column of air is longest, the mean height of the barometer is 30 inches. This Sir George Shuckburgh found to be the case in the Mediterranean and the Channel, in the temperature of 55° and 60°; Mr Bouguer, on the coast of Peru, in the temperature of 84°; and Lord Mulgrave, in latitude 80°. The mean height of the barometer is less the higher any place is situated above the level of the sea, because the column of air which supports the mercury is the shorter. The barometer has accordingly been used for measuring heights. But if a barometer be allowed to remain in one place, the mercury does not continue stationary; sometimes it rises and at other times falls, varying to the extent of several inches: of course the weight of the air which balances the mercury must be subject to the same changes. Hence we learn that the air in the same place is sometimes light and at other times heavy; differences which must be owing to changes in its quantity. The barometer then informs us that the quantity of air above any spot is liable to continual alterations. Consequently either the air accumulates in particular spots, while

Variation.

it partially abandons others; or 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. From the observations of Mr Horsburgh we learn, that in the tropical seas, that is, from north latitude 26° to south latitude 27°, the mercury reached its greatest height at eight A. M. and continued stationary till noon. After noon it began to fall, and continued falling till four P. M. at which time it arrived at the lowest point of depression. From four or five P. M. the mercury rose again, and continued rising till about nine or ten P. M. at which time it had again acquired its greatest point of elevation, and continued stationary nearly till midnight, after which it began to fall, till at four A. M. it was again as low as it had been at four afternoon. From this time it rose till seven or eight o'clock, when it reached its highest point of elevation †. Mr Horsburgh observed, that these diurnal elevations and depressions, which he calls *equatropical motions*, were performed regularly while at sea; but when the barometers were carried ashore, or when the vessel was in a river, they could seldom be observed. It is difficult to conceive a reason for this singular fact, unless we suppose

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* M. Cassan, *Jour. de Phys.* April 1790, p. 268.

† Nicholson's *Jour.* xiii. 17.

it connected with the motion of the ship, which, by regularly agitating the mercury, might make its elevations and depressions more sensible and correct than when the barometer continues stationary.

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° 0′	Peru	0·20 [*]	—
22 23	Calcutta	0·77 [†]	—
33 55	Cape Town	—	0·89 [‡]
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

In North America, however, the range of the barometer is a great deal less than in the corresponding European latitudes. In Virginia, for instance, it never exceeds 1·1 [‖].

The range of the barometer is greater at the level of the sea than on the mountains; and in the same degree

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[*] Kirwan, *Irish Trans.* vol. iii. p. 47.

[†] *Asiatic Researches*, vol. ii. Appendix.

[‡] Barrow's *Travels*, p. 42.

[§] *Manchester Trans.* vol. iv.

[**] *Edinburgh Trans.* vol. ii. p. 229.

[‖] *Trans. Philadel.* vol. ii. p. 142.

of latitude, the extent of the range is in the inverse ratio of the height of the place above the level of the sea.

Diurnal range.

From a table published by Mr Cotte in the *Journal de Physique* *, it seems exceedingly probable that the barometer has always a tendency to rise from the morning to the evening; and that this tendency is greatest between two o'clock in the afternoon and nine at night, at which hour the greatest elevation takes place; that the elevation of nine o'clock differs from that of two by $\frac{4}{12}$ths, while that at two differs from the morning elevation only by $\frac{1}{12}$th; and that in certain climates the greatest elevation takes place at two o'clock. The following is a part of the Table on which these observations are founded, reduced to the English standard.

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* Aug. 1790, p. 110.

Places.	Years of observation	Mean Height of the 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	29·7895	29·8001	29·7859
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	29·7127
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

From the observations of Mr Luke Howard, as confirmed by Cotte, it appears that the barometer has a tendency to sink at new and full moon, and to rise at the quarters. This coincidence is greatest in calm and fair weather. The depression from the quarters to the conjunctions amounts to $\frac{1}{10}$th inch; and the elevation from the conjunctions to the quarters amounts to the same quantity.

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 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 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

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* *Manchester Trans.* vol. iv. p. 543. † Dr Halley.

‡ *Asiatic Researches*, vol. ii. Appendix.

§ *Manchester Trans.* vol. iv.

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 the greatest. The height 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

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[*] Kirwan, *Irish Trans.* vol. ii. p. 43, &c.

[†] Dr Guthrie, *Edin. Trans.* vol. ii. p. 229.

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 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 hemisphere; 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 height takes 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 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 possible 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 height 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 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 ATMOSPHERE.

THAT the temperature of the air varies considerably, not only in the different climates and in different seasons, but even in the same place and in the same season, must be obvious to the most careless observer. This perpetual variation cannot be ascribed to the direct heat of the sun; for the rays of that luminary seem to produce no effect whatever upon air, though ever so much concentrated: but they warm the surface of the earth, which communicates its heat to the surrounding atmosphere. Hence it happens that the temperature of the air is highest in those places which are so situated as to be most warmed by the sun's rays, and that it varies in every region with the season of the year. Hence, too, the reason why it diminishes according to the height of the air above the surface of the earth. That portion of the earth which lies at the equator is exposed to the most perpendicular rays of the sun. Of course it is hottest, and the heat of the earth diminishes gradually from the equator to the poles. The temperature of the air must follow the same order. The air, then, is hottest over the equator, and its temperature gradually diminishes from the equator to the poles, where it is coldest of all. It is hottest at the equator, and it becomes gradually colder according to its height above that surface. Let us examine the nature of these two diminishing progressions of temperature.

Method of ascertaining the mean annual temperature.

1. Though the temperature of the air is highest at the equator, and gradually sinks as it approaches the pole; yet as, in every place, the temperature of the air is constantly varying with the season of the year, we cannot form any precise notion of the progression without taking the temperature in every degree of latitude for every day of the year, and forming from each a mean temperature for the whole year; which is done by adding together the whole observations, and dividing by their number. The quotient gives the mean temperature for the year. The diminution from the pole to the equator takes place in arithmetical progression: or, to speak more properly, the annual temperature of all the latitudes are arithmetical means between the mean annual temperature of the equator and the pole. This was first discovered by Mr Meyer; and by means of an equation which he founded on it, but rendered considerably plainer and simpler, Mr Kirwan has calculated the mean annual temperature of every degree of latitude between the equator and the pole. He proceeded on the following principle: Let the mean annual heat at the equator be m, and at the pole $m-n$; put Φ for any other latitude; the mean annual temperature of that latitude will be $m-n\times\sin.\ \Phi^2$. If therefore the temperature of any two latitudes be known, the value of m and n may be found. Now the temperature of north lat. 40° has been found by the best observations to be 62·1°, and that of lat. 50°, 52·9°. The square of the sine of 40° is nearly 0·419, and the square of the sine of 50° is nearly 0·586. Therefore

$$m - 0{\cdot}41\ n = 62{\cdot}1, \text{ and}$$

$$m - 0{\cdot}58\ n = 52{\cdot}9; \text{ therefore}$$

$62{\cdot}1 + 0{\cdot}41\ n = 52{\cdot}9 + 0{\cdot}58\ n$, as each of them, from the two first equations, is equal to m. From this last equation the value of n is found to be 53 nearly; and m is nearly equal to 84. The mean temperature of the equator therefore is 84°, and that of the pole 31°. To find the mean temperature for every other latitude, we have only to find 88 arithmetical means between 84 and 31. In this manner Mr Kirwan calculated the following Table:

TABLE *of the Mean Annual Temperature of the Standard Situation in every Latitude.*

Lat.	Temper.	Lat.	Temper.	Lat.	Temper.	Lat.	Temper.
90	31·	68	38·4	46	56·4	24	75·4
89	31·04	67	39·1	45	57·5	23	75·9
88	31·10	66	39·7	44	58·4	22	76·5
87	31·14	65	40·4	43	59·4	21	77·2
86	31·2	64	41·2	42	60·3	20	77·8
85	31·4	63	41·9	41	61·2	19	78·3
84	31·5	62	42·7	40	62·	18	78·9
83	31·7	61	43·5	39	63·	17	79·4
82	32·	60	44·3	38	63·9	16	79·9
81	32·2	59	45·09	37	64·8	15	80·4
80	32·6	58	45·8	36	65·7	14	80·8
79	32·9	57	46·7	35	66·6	13	81·3
78	33·2	56	47·5	34	67·4	12	81·7
77	33·7	55	48·4	33	68·3	11	82·
76	34·1	54	49·2	32	69·1	10	82·3
75	34·5	53	50·2	31	69·9	9	82·7
74	35·	52	51·1	30	70·7	8	82·9
73	35·5	51	52·4	29	71·5	7	83·2
72	36·	50	52·9	28	72·3	6	83·4
71	36·6	49	53·8	27	72·8	5	83·6
70	37·2	48	54·7	26	73·8	0	84·
69	37·8	47	55·6	25	74·5		

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 $\frac{54\cdot 6+52\cdot 4}{2}=48\cdot 5$.

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°	70°	69°	68°	67°	66°	65°	64°	63°
Jan.	22·	22·5	23·	23·5	24·	24·5	25·	25·5	26·	26·5	27·	27·5	27·5	28·	28·	28·	29·	30·
Feb.	23·	23·	23·5	24·	24·5	25·	25·5	26·	26·5	27·	27·5	28·	28·	28·5	29·	30·	31·	32·
March	27·	27·5	28·	28·5	29·	29·5	30·	30·5	31·	31·5	32·	32·5	33·	33·5	34·	35·	36·	37·
April	32·6	32·9	33·2	33·7	34·1	34·5	35·	35·5	36·	36·6	37·2	37·8	38·4	39·1	39·7	40·4	41·2	41·9
May	36·5	36·5	37·	37·5	38·	38·5	39·	39·5	40·	40·5	41·	41·5	42·	42·5	43·	44·	45·	46·
June	51·	51·	51·5	52·	52·	52·	52·5	53·	53·5	54·	54·	54·5	54·5	54·5	55·	55·	55·5	55·5
July	50·	50·	50·5	51·	51·	51·	51·5	52·	52·5	53·	53·5	53·5	53·5	54·	54·5	54·5	55·	55·
August	39·5	40·	41·	41·5	42·	42·5	43·	43·5	44·	44·5	45·	45·5	46·	47·	48·	48·5	49·	50·
Sept.	33·5	34·	34·5	35·	35·5	36·	36·5	37·	38·	38·5	39·	39·5	40·	41·	42·	43·	44·	45·
Octob.	28·5	29·	29·5	30·	30·5	31·	31·5	32·	32·5	33·	33·5	34·	34·	35·	36·	37·	37·5	38·
Nov.	23·	23·5	24·	24·5	25·	25·5	26·	26·5	27·	27·5	28·	28·5	29·	30·	31·	32·	32·5	33·
Dec.	22·5	23·	23·5	24·	24·5	25·	25·5	26·	26·5	27·	27·5	28·	28·	29·	30·	30·5	31·	31·

TABLE *of the Monthly Mean Temperature, &c. continued.*

Lat.	62°	61°	60°	59°	58°	57°	56°	55°	54°	53°	52°	51°	50°	49°	48°	47°	46°	45°
Jan.	31·	32·	33·	34·	35·	36·	37·	38·	39·	40·	41·	42·	42·5	43·5	43·	43·5	44·	44·5
Feb.	33·	34·	35·	36·	37·	38·	39·	40·	41·	42·	43·	44·	44·5	44·5	45·	45·5	46·	46·5
March	38·	39·	40·	41·	42·	43·	44·6	45·	46·	48·	49·	50·	50·5	51·	52·5	53·	53·5	54·5
April	42·7	43·5	44·3	45·09	45·8	46·7	47·5	48·4	49·2	50·2	51·1	52·4	52·9	53·8	54·7	55·6	56·4	57·5
May	47·	48·	49·	50·	51·	52·	53·	54·	55·	56·	57·	58·	58·5	59·	60·	61·	62·	63·
June	56·	56·	56·	56·5	57·	57·	57·5	58·	58·5	59·	59·	60·	61·	62·	63·	64·	65·	66·
July	55·5	55·5	56·	56·5	57·	57·5	58·	59·	60·	61·	62·	63·	63·5	64·	65·	66·	67·	68·
August	51·	52·	53·	54·	55·	56·	57·	58·	59·	60·	61·	62·	63·5	64·	65·	66·	67·	68·
Sept.	46·	47·	48·	49·	50·	51·	52·	53·	54·	55·	56·	57·	58·5	59·	60·	61·	62·	63·
Octob.	39·	40·	41·	42·	43·	44·	45·	46·	47·	48·	49·	50·	50·5	51·	52·	53·	54·	55·
Nov.	34·	35·	36·	37·	38·	39·	40·	41·	42·	43·	44·5	46·	46·5	47·	48·	49·	50·	51·
Dec.	32·	33·	34·	35·	36·	37·	38·	39·	40·	41·	42·	44·	44·5	45·	46·	47·	48·	49·

TABLE *of the Monthly Mean Temperature, &c. continued.*

Lat.	44°	43°	42°	41°	40°	39°	38°	37°	36°	35°	34°	33°	32°	31°	30°	29°	28°	27°
Jan.	45·	45·5	46·	46·5	49·5	51·	52·	53·5	55·	56·5	59·5	63·	63·	63·	63·5	63·5	63·5	64·
Feb.	47·	48·	49·	50·	53·	56·5	58·	60·	61·	62·	63	64·5	66·	67·	68·5	68·5	69·5	69·5
March	55·5	56·5	58·5	59·5	60·	60·5	61·	62·	63·	64·	65·	66·5	67·5	68·5	69·5	71·	72·	72·5
April	58·4	59·4	60·3	61·2	62·1	63·	63·9	64·8	65·7	66·6	67·4	68·3	69·1	69·9	70·7	71·5	72·3	72·8
May	64·	65·	66·	67·	68·	69·	70·	70·5	71·	71·5	72·	72·5	73·	73·	73·5	74·5	75·5	76·
June	67·	68·	69·	70·	70·5	71.	71·	71·	71·5	71·5	72·	72·5	73·	73·	73·5	74·5	75·5	76·
July	69·	69·5	70·	70·	71·	71·	72·	72·	72·5	72·5	72·5	72·5	73·	73·	73·5	74·5	75·5	76·
August	69·	69·5	70·	70·	71·	71·	72·	72·	72·5	72·5	72·5	72·5	73·	73·	73·5	74·5	75·5	76·
Sept.	64·	66·	68·	69·5	70·5	71·	71·5	72·	72·5	72·5	72·5	72·5	73·	73·	73·5	74·	75·5	76·
Octob.	56·	57·	58·	59·	60·	61·	62·	63·	64·	65·	66·	67·5	68·5	69·5	70·5	71·	72·5	72·5
Nov.	52·	53·	54·	55·	56·	57·	58·	59·	60·	61·	62·	63·	64·5	65·5	66·5	68·	69·	69·5
Dec.	50·	51·	52·	53·	54·	55·	56·	57·	58·	59·	60·	61·	62·5	63·5	64·5	66·	67·	67·5

TABLE *of the Monthly Mean Temperature, &c. continued.*

Lat.	26°	25°	24°	23°	22°	21°	20°	19°	18°	17°	16°	15°	14°	13°	12°	11°	10°
Jan.	64·5	65·5	67·	68·	69·	71·	72·	72·5	73·	73·5	74·	74·5	75·	76·	76·5	77·	77·5
Feb.	70·5	71·	72·	72·	72·5	74·	75·	76·	76·5	77·	77·5	78·	78·5	79·	79·5	79·8	80·
March	73·	73·5	74·5	75·	75·5	76·	77·	77·5	78·	78·5	79·	79·5	80·	80·8	81·	81·5	81·8
April	73·8	74·5	75·4	75·9	76·5	77·2	77·8	78·3	78·9	79·4	79·9	80·4	80·8	81·3	81·7	82·	82·3
May	76·5	77·5	78·	78·5	79·5	80·	80·5	81·	81·5	82·	82·5	83·	83·	83·5	84·	84·	84·3
June	76·5	78·	78·5	79·	79·5	80·	80·5	81·5	82·	82·5	83.	83·5	83·8	84·	84·3	84·6	84·8
July	76·5	78·	78·5	79·	79·5	80.	80·5	81·5	82·	82·5	83.	83·5	83·8	84·	84·3	84·6	84·8
August	76·5	78·	78·5	79·	79·5	80.	80·5	81·5	82·	82·5	83·	83·5	83·8	84·	84·3	84·6	84·8
Sept.	76·5	77·5	78·	78·5	79·	79·5	80·	81·	81·5	82·	82·5	83·	83·	83·5	84·	84·3	84·6
Octob.	73·	73·5	74·5	75·	75·5	77·	78·	79·	80·	81·	81·5	82·	82·5	83·	83·5	83·8	84·
Nov.	71·5	72·	73·5	74·	74·5	75·	75·5	76·	77·	78·	78·5	79·	79·5	80·	80·5	80·8	81·
Dec.	68·5	69·5	70·	71·	71·5	72·	72·5	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 hottest 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 differ very little, neither do they differ much within ten degrees of the equator; the temperatures of different years differ very little near the equator, but they differ more and more as the latitudes approach the poles.

Temperature diminishes with the height of the air.

2. That the temperature of the atmosphere gradually diminishes, according to its height above the level of the sea, is well known. Thus the late Dr Hutton of Edinburgh found that a thermometer, kept on the top of Arthur's Seat, usually stood three degrees lower than a thermometer kept at the bottom of it. Hence, then, a height of 800 feet occasioned 3° of diminution of temperature. On the summit of Pinchinca the thermometer stood at 30°, as observed by Bouguer, while at the level of the sea in the same latitude it stood at 84°. Here a height of 15,564 feet occasioned a diminution of temperature amounting to 54°. But though there can be no doubt of the gradual diminution of temperature, according to the height, it is by no means easy to determine the rate of diminution. Euler supposes it to be in a harmonic progression; but this opinion is contradicted by observations. Saussure supposes, that in temperate climates the diminution of temperature amounts to 1° for every 287 feet of elevation. But Mr Kirwan has shown that no such rule holds, and that the rate of diminution va-

ries with the temperature at the surface of the earth. We are indebted to this philosopher for a very ingenious method of determining the rate of diminution in every particular case, supposing the temperature at the surface of the earth known *.

Since the temperature of the atmosphere is constantly diminishing as we ascend above the level of the sea, it is obvious, that at a certain height we arrive at the region of perpetual congelation. This region varies in height according to the latitude of the place; it is highest at the equator, and descends gradually nearer the earth as we approach the poles. It varies also according to the season, being highest in summer and lowest in winter. M. Bouguer found the cold on the top of Pinchinca, one of the Andes, to extend from seven to nine degrees below the freezing point every morning immediately before sun-rise. He concluded, therefore, that the mean height of the *term of congelation* (the place where it freezes during some part of the day all the year round) between the tropics was 15,577 feet above the level of the sea; but in lat. 28° he placed it in summer at the height of 13,440 feet. Now, if we take the difference between the temperature of the equator and the freezing point, it is evident that it will bear the same proportion to the term of congelation at the equator that the difference between the mean temperature of any other degree of latitude and the freezing point bears to the term of congelation in that latitude. Thus the mean heat of the equator being 84°, the difference between it and 32 is 52; the mean heat

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* *Irish Trans.* viii. 356.

of latitude 28° is 72·3°, the difference between which and 32 is 40·3: Then 52 : 15577 : : 40·3 : 12072. In this manner Mr Kirwan 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

Beyond this height, which has been called the lower term of congelation, and which must vary with the season and other circumstances, Mr Bouguer has distinguished another, which he called the *upper* term of congelation; that is, the point above which no visible vapour ascends. Mr Kirwan considers this line as much less liable to vary during the summer months than the lower term of congelation, and therefore has made choice of it to determine the rate of the diminution of heat, as we ascend in the atmosphere. Bouguer determined the height of this term in a single case, and Kirwan has calculated the following Table of its height for every degree of latitude in the northern hemisphere *.

TABLE of the Height of the Upper Line of Congelation in the different Latitudes of the Northern Hemisphere.

N. Lat	Feet.	N Lat.	Feet.	N Lat	Feet.	N.. Lat	Feet.
0°	28000	26°	22906	48	12245	70	4413
5	27784	27	22389	49	11750	71	4354
6	27644	28	21872	50	11253	72	4295
7	27504	29	21355	51	10124	73	4236
8	27364	30	20838	52	8965	74	4177
9	27224	31	20492	53	7806	75	4119
10	27084	32	20146	54	6647	76	4067
11	26880	33	19800	55	5617	77	4015
12	26676	34	19454	56	5533	78	3963
13	26472	35	19169	57	5439	79	3911
14	26268	36	18577	58	5345	80	3861
15	26061	37	17985	59	5251	81	3815
16	25781	38	17393	60	5148	82	3769
17	25501	39	16801	61	5068	83	3723
18	25221	40	16207	62	4989	84	3677
19	24941	41	15712	63	4910	85	3631
20	24661	42	15217	64	4831	86	3592
21	24404	43	14722	65	4752	87	3553
22	24147	44	14227	66	4684	88	3514
23	23890	45	13730	67	4616	89	3475
24	23633	46	13235	68	4548	90	3432
25	23423	47	12740	69	4480		

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* For the method which Mr Kirwan followed in constructing this Table, the reader is referred to his *Estimate of the Temperature of different Climates*, and his Essay *On the Variation of the Atmosphere.*

The following rule of Mr Kirwan will enable us to ascertain the temperature at any required height, provided we know the temperature at the surface of the earth.

How calculated.

Let the observed temperature at the surface of the earth be $= m$, the height given $= h$, and the height of the upper term of congelation for the given latitude be $= t$; then $\frac{m - 32}{\frac{t}{100} - 1}$ = the diminution of temperature for every hundred feet of elevation; or it is the common difference of the terms of the progression required. Let this common difference thus found be denoted by c; then $c \times \frac{h}{100}$ gives us the whole diminution of temperature from the surface of the earth to the given height. Let this diminution be denoted by d, then $m - d$ is obviously the temperature required. An example will make this rule sufficiently obvious. In latitude 56°, the heat below being 54°, required the temperature of the air at the height of 803 feet?

Here $m = 54$, $t = 5533$, $\frac{m - 32}{\frac{t}{100} - 1} = \frac{22}{54{\cdot}33} = 0{\cdot}404 = c$, and $c \times \frac{h}{100} = 0{\cdot}404 \times 8{\cdot}03 = 3{\cdot}24 = d$, and $m - d = 54 - 3{\cdot}24 = 50{\cdot}75$. Here we see that the temperature of the air 803 feet above the surface of the earth is 50·75°.

From this method of estimating the diminution of temperature, which agrees remarkably well with observation, we see that the heat diminishes in an arithmetical progression. Hence it follows, that the heat of the air at a distance from the earth, is not owing to the ascent of hot strata of air from the surface of the earth, but to the conducting power of the air.

Upper regions warmest in winter.

3. This rule, however, applies only to the temperature of the air during the summer months of the year. In winter the upper strata of the atmosphere are often warmer than the lower. Thus on the 31st of January 1776, the thermometer on the summit of Arthur's Seat stood six degrees higher than a thermometer at Hawkhill, which is 684 feet lower *. Mr Kirwan considers this superior heat, almost uniformly observed during winter, as owing to a current of warm air from the equator, which rolls towards the north pole during our winter †.

4. 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 four or five degrees below the standard. But we are not yet furnished with a sufficient number of observations to determine this with accuracy.

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* Roy, *Phil. Trans.* 1777, p. 777.

† *Irish Trans.* viii. p. 375.

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 northern hemisphere. Mr Kirwan has shown that this holds with respect to the summer of the southern hemisphere, but that the winter in the same latitudes is milder than in the northern hemisphere *.

3. Small seas.

Small seas surrounded with land, at least in temperate 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 re-

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* *Irish Trans.* viii. 417.

† *Mem. Stock.* 1776.

‡ Kirwan's *Temperature of Lat.* p. 53.

§ Ibid.

‖ For the following statement of the extremes of heat and cold at Montreal and Three Rivers in Canada, I am indebted to an ingenious officer, who kept a register for eight years, from the year 1776 to 1784 inclusive.

markable 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 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 coldness 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 clear-

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" In the warmest summer the thermometer was not observed to rise higher than 94°, though it has been said to have risen so high as 96° and even 98° at Quebec; but where these observations were made, the thermometer was generally from 80° to 84° in the warmest summers, and the average of the ordinary summers was about 70°.

" In the severe frosts the thermometer sunk to 45° below 0. This happened three times within this period, viz. on the 23d and 25th February 1782, and on the 10th February 1784.

" In the ordinary winters, at Three Rivers, the mercury stood at from 10° to 25° below 0, and in the severe winters from 25° to 35° below 0.

" The summer observations were taken at about nine o'clock in the morning, and three in the afternoon. The winter before sun-rise, and about nine, and sometimes ten o'clock at night."

ed 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.

ON 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 Deluc 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 of the same elasticity, according to Saussure, as 10 to 14, or, according to Kirwan, as 10 to 12. It cannot pass beyond a certain maximum of density, without a corresponding increase of temperature, otherwise the particles of water which compose it unite together, and form small, visible particles, 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.

We have seen formerly, that when water is heated to 212°, it boils, and is rapidly converted into steam ; and that the same change takes place in much lower temperatures ; but in that case the evaporation is slower, and the elasticity of the steam is smaller. As a very considerable proportion of the earth's surface is covered with water, and as this water is constantly evaporating and mixing with the atmosphere in the state of vapour, a precise determination of the rate of evaporation must be of very great importance in meteorology. Accordingly many experiments have been made to determine the point by different philosophers. No person has succeeded so completely as Mr Dalton : But many curious particulars had been previously ascertained by the labours of Richman, Lambert, Wallerius, Leidenfrost, Watson, Saussure, Deluc, Kirwan, and others.

Evaporation confined to the surface.

1. The evaporation is confined entirely to the surface of the water : hence it is in all cases proportional to the surface of the water exposed to the atmosphere. Much more vapour of course rises in maritime countries, or those interspersed with lakes, than in inland countries.

2. Much more vapour rises during hot weather than during cold weather. Hence the quantity evaporated depends in some measure upon temperature. The precise

Evaporation proportional to the temperature.

law has been happily discovered by Mr Dalton. This philosopher took a cylindrical vessel of tin, whose diameter was $3\frac{1}{4}$ inches, and its depth $2\frac{1}{2}$ inches; filled it with water, and kept it just boiling for some time. The loss of weight in the minute was 30 grains, when the experiment was made in a close room without any draught of air; 35 grains when the vessel was placed over fire in the usual fire-place, there being a moderate draught of air and the room close; 40 with a brisker fire and a stronger draught; and when the draught was very strong, he supposes the evaporation might amount to 60 grains in the minute. At the temperature of 180°, the quantity evaporated was $\frac{1}{2}$ of what was lost at 212°.

At 164 it was $\frac{1}{3}$ of that at 212°
152 ...... $\frac{1}{4}$
144 ...... $\frac{1}{5}$
138 ...... $\frac{1}{6}$

And in general the quantity evaporated from a given surface of water *per* minute at any temperature, is to the quantity evaporated from the same surface at 212°, as the force of vapour at the first temperature is to the force of vapour at 212°. Hence, in order to discover the quantity which will be lost by evaporation from water of a given temperature, we have only to ascertain the force of vapour at that temperature. This is done in the Table given in Vol. I. p. 537. of this Work. Hence we see that the presence of atmospheric air obstructs the evaporation of water; but this resistance is overcome in proportion to the force of the vapour.

3. The quantity of vapour which rises from water, even when the temperature is the same, varies according to circumstances. It is least of all in calm weather, greater when a breeze blows, and greatest of all with a strong wind. The following Table, drawn up

Chap. II.

Table of the quantity raised from a given surface at different temperatures.

by Mr Dalton, shows the quantity of vapour raised from a circular surface of six inches in diameter in atmospheric temperatures. The first column expresses the temperature; the second, the corresponding force of vapour; the other three columns give the number of grains of water that would be evaporated from a surface of six inches in diameter in the respective temperatures, on the supposition of there being previously no aqueous vapour in the atmosphere. These columns present the extremes and the mean of evaporation likely to be noticed, or nearly such; for the first is calculated upon the supposition of 35 grains loss *per* minute from the vessel of $3\frac{1}{4}$ inches in diameter; the second 45, and the third 55 grains *per* minute[*].

Temperature.	Force of Vap. in Inch.	Evaporating Force in Grains.		
212°	30	120	154	189
20°	·129	·52	·67	·82
21	·134	·54	·69	·85
22	·139	·56	·71	·88
23	·144	·58	·73	·91
24	·150	·60	·77	·94
25	·156	·62	·79	·97
26	·162	·65	·82	1·02
27	·168	·67	·86	1·05
28	·174	·70	·90	1·10
29	·180	·72	·93	1·13
30	·186	·74	·95	1·17
31	·193	·77	·99	1·21
32	·200	·80	1·03	1·26
33	·207	·83	1·07	1·30
34	·214	·86	1·11	1·35
35	·221	·89	1·14	1·39
36	·229	·92	1·18	1·45
37	·237	·95	1·22	1·49
38	·245	·98	1·26	1·54

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[*] *Manchester Memoirs*, v. 584.

Temperature. 212°	Force of Vap. in Inch. 30	Evaporating Force in Grains. 120	154	189
39°	·254	1·02	1·31	1·60
40	·263	1·05	1·35	1·65
41	·273	1·09	1·40	1·71
42	·283	1·13	1·45	1·78
43	·294	1·18	1·51	1·85
44	·305	1·22	1·57	1·92
45	·316	1·26	1·62	1·99
46	·327	1·31	1·68	2·06
47	·339	1·36	1·75	2·13
48	·351	1·40	1·80	2·20
49	·363	1·45	1·86	2·28
50	·375	1·50	1·92	2·36
51	·388	1·55	1·99	2·44
52	·401	1·60	2·06	2·51
53	·415	1·66	2·13	2·61
54	·429	1·71	2·20	2·69
55	·443	1·77	2·28	2·78
56	·458	1·83	2·35	2·88
57	·474	1·90	2·43	2·98
58	·490	1·96	2·52	3·08
59	·507	2·03	2·61	3·19
60	·524	2·10	2·70	3·30
61	·542	2·17	2·79	3·41
62	·560	2·24	2·88	3·52
63	·578	2·31	2·97	3·63
64	·597	2·39	3·07	3·76
65	·616	2·46	3·16	3·87
66	·635	2·54	3·27	3·99
67	·655	2·62	3·37	4·12
68	·676	2·70	3·47	4·24
69	·698	2·79	3·59	4·38
70	·721	2·88	3·70	4·53
71	·745	2·98	3·83	4·68
72	·770	3·08	3·96	4·84
73	·796	3·18	4·09	5·00
74	·823	3·29	4·23	5·17

Temperature.	Force of Vap. in Inch.	Evaporating Force in Grains.		
212°	30	120	154	189
75	·851	3·40	4·37	5·34
76	·880	3·52	4·52	5·53
77	·910	3·65	4·68	5·72
78	·940	3·76	4·83	5·91
79	·971	3·88	4·99	6·10
80	1·00	4·00	5·14	6·29
81	1·04	4·16	5·35	6·54
82	1·07	4·28	5·50	6·73
83	1·10	4·40	5·66	6·91
84	1·14	4.56	5·86	7·17
85	1·17	4·68	6·07	7·46

Method of finding the rate of evaporation.

4. Such is the quantity of vapour which would rise in different circumstances, on the supposition that no vapour previously existed in the atmosphere. But this is a supposition which can never be admitted, as the atmosphere is in no case totally free from vapour. We have seen already in what manner the force of the vapour existing in the atmosphere may be detected by the use of Mr Dalton's very simple apparatus. Now when we wish to ascertain the rate at which evaporation is going on, we have only to find the force of the vapour already in the atmosphere, and subtract it from the force of vapour at the given temperature. The remainder gives us the actual force of evaporation; from which, by the Table, we readily find the rate of evaporation. Thus suppose we wish to know the rate of evaporation at the temperature 59°. From the table we see that the force of vapour at 59° is 0·5, or $\frac{1}{60}$th its force at 212°. Suppose we find by trials that the force of the vapour already existing in the atmosphere is 0·25, or the half of $\frac{1}{60}$th. To ascertain the rate of evaporation,

we must subtract the 0·25 from 0·5; the remainder 0·25 gives us the force of evaporation required; which is precisely one half of what it would be if no vapour had previously existed in the atmosphere.

By the Table we see, that on that supposition a surface of six inches diameter would lose one grain by evaporation per minute, instead of two grains, which would have been converted into vapour if no vapour had previously existed in the atmosphere. If the force of the vapour in the atmosphere had amounted to 0·5, which is equal to the force of vapour at the temperature of 59°, in that case no vapour whatever would rise from the water: and if the force of the vapour already in the atmosphere exceeded 0·5, instead of evaporation, moisture would be deposited on the surface of the water.

These general observations, for all of which we are indebted to Mr Dalton, account in a satisfactory manner for most of the anomalies which had puzzled preceding philosophers; and include under them the less general laws which they had discovered. We must consider the discoveries of Mr Dalton as the most important additions made to the science of meteorology for these many years.

5. As the force of the vapour actually in the atmosphere is seldom equal to the force of vapour of the temperature of the atmosphere, evaporation, with a few exceptions, may be considered as constantly going on.

Quantity evaporated from water;

Various attempts have been made to ascertain the quantity evaporated in the course of a year; but the difficulty of the problem is so great, that we can expect only an approximation towards a solution. From the experiments of Dr Dobson of Liverpool, in the years 1772, 1773, 1774, and 1775, it appears that the mean annual evaporation from the surface of water amounted to 36·78 inches[*]. The proportion for every month was the following:

	Inches.		Inches.
January	1·50	July	5·11
February	1·77	August	5·01
March	2·64	September	3·18
April	3·30	October	2·51
May	4·34	November	1·51
June	4·41	December	1·49

Mr Dalton found the evaporation from the surface of water, in one of the driest and hottest days of summer, rather more than 0·2 of an inch.

From land.

If we believe Mr Williams, the evaporation from the surface of land covered with trees and other vegetables is one third greater than from the surface of water; but this has not been confirmed by other philosophers. From his experiments[†] it appears, that in Bradford in New England the evaporation during 1772 amounted to 42·65 inches. But from the way that his experiments were conducted, the amount was probably too great.

From an experiment of Dr Watson, made on the 2d of June 1779, after a month's drought, it appears that the evaporation, from a square inch of a grass plot, amounted to 1·2 grains in an hour, or 28·8 grains in 24 hours, which is 0·061 of an inch. In another experiment after there had been no rain for a week, the heat of the earth being 110°, the evaporation was found

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[*] *Phil. Trans.* vol. lxvii—Dalton, *Manchester Memoirs*, v. 358.

[†] *Trans. Philad.* ii. 135.

almost twice as great, or = 0·108 of an inch in the day *. The mean of these two experiments is 0·084 inches, amounting for the whole month of June to 2·62 inches. If we suppose this to bear the same proportion to the whole year that the evaporation in Dr Dobson's experiments for June do to the annual evaporation, we shall obtain an annual evaporation amounting to about 22 inches. This is much smaller than that obtained by Mr Williams. But Dr Watson's method was not susceptible of precision. He collected the vapour raised on the inside of a drinking-glass; but it was impossible that the glass could condense much more than one half of what did rise, or would have been raised, in other circumstances. But to counterbalance this, the experiments were made in the hottest part of the day, when much more vapour is raised than during any other part of it.

Experiments of Dalton.

The most exact set of experiments on the evaporation from earth was made by Mr Dalton and Mr Hoyle during 1796 and the two succeeding years. The method which they adopted was this. Having got a cylindrical vessel of tinned iron, 10 inches in diameter and three feet deep, there were inserted into it two pipes turned downwards for the water to run off into bottles: The one pipe was near the bottom of the vessel; the other was an inch from the top. The vessel was filled up for a few inches with gravel and sand, and all the rest with good fresh soil. It was then put into a hole in the ground, and the space around filled up with earth except on one side, for the convenience of putting bot-

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* Watson's *Chemical Essays*, iii. 54.

tles to the two pipes; then some water was poured on to sadden the earth, and as much of it as would was suffered to run through without notice, by which the earth might be considered as saturated with water. For some weeks the soil was kept above the level of the upper pipe, but latterly it was constantly a little below it, which precluded any water running off through it. For the first year the soil at top was bare; but for the two last years it was covered with grass the same as any green field. Things being thus circumstanced, a regular register was kept of the quantity of rain-water that ran off from the surface of the earth through the upper pipe (whilst that took place), and also of the quantity of that which sunk down through the three feet of earth, and ran out through the lower pipe. A rain-gauge of the same diameter was kept close by to find the quantity of rain for any corresponding time. The weight of the water which ran through the pipes being subtracted from the water in the rain-gauge, the remainder was considered as the weight of the water evaporated from the earth in the vessel. The following TABLE exhibits the mean annual result of these experiments *.

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* *Manchester Memoirs*, v. p. 360.

	Water through the two Pipes. Inch 1796.	Inch. 1797.	Inch. 17,8.	Mean Inch.	Mean Rain Inch.	Mean. Evap. Inch.
Jan..........	1·897—	·680—	1·774+	1·450+	2·458	1·008
Feb.........	1·778—	·918—	1·122	1·273	1·801	·528
March......	·431—	·070—	·335	·279	·902	·623
April.......	·220—	·295—	·180	·232	1·717	1·485
May........	2·027—	2·443+	·010	1·493+	4·177	2·684
June........	·171—	·726	——	·299	2·483	2·184
July........	·153—	·025	——	·059	4·154	4·095
August......	——	——	·504	·168	3·554	3·386
Sept.........	——	·976	——	·325	3·279	2·954
October.....	——	·680	——	·227	2·899	2·672
Nov.........	——	1·044	1·594	·879	2·934	2·055
Dec.........	·200	3·077	1·878+	1·718+	3·202	1·484
	6·877—	10·934—	7·379	8·402	33·560	25·158
Rain....	30·629—	38·791—	31·259			
Evapor..	23·725—	27·857—	23·862			

From these experiments it appears, that the quantity of vapour raised annually at Manchester is about 25 inches: if to this we add 5 inches for the dew, with Mr Dalton, it will make the annual evaporation 30 inches. Now if we consider the situation of England, and the greater quantity of vapour raised from water, it will not surely be considered as too great an allowance if we estimate the mean annual evaporation over the whole surface of the globe at 35 inches. Now 35 inches from every square inch on the superficies of the globe make 94,450 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 Deluc, 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 Deluc, 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 dissolved in rain. Clouds, however, are not formed in all parts of the horizon at once; the formation begins in one particular spot, while the rest of the air remains clear as before: this cloud rapidly increases till it overspreads the whole horizon, and then the rain begins.

Formation of clouds.

It is remarkable, that though the greatest quantity of vapours exist in the lower strata of the atmosphere, clouds never begin to form there, but always at some considerable height. It is remarkable, too, that the part of the atmosphere at which they form, has not arrived at the point of extreme moisture, nor near that point, even a moment before their formation. They are not formed, then, because a greater quantity of vapour had got into the atmosphere than could remain there without passing its maximum. It is still more remarkable, that when clouds are formed, the temperature of the spot in which they are formed is not always lowered, though this may sometimes be the case. On the contrary, the heat of the clouds themselves is sometimes greater than that of the surrounding air *. Neither, then, is the formation of clouds owing to the capacity of air for combining with moisture being lessened by cold; so far from that, we often see clouds, which had remained in the atmosphere during the heat of the day, disappear in the night, after the heat of the air was diminished.

And rain cannot be accounted for.

The formation of clouds and rain, then, cannot be accounted for by the principles with which we are acquainted. It is neither owing to the saturation of the atmosphere, nor the diminution of heat, nor the mixture of airs of different temperatures, as Dr Hutton supposed; for clouds are often formed without any wind at all either above or below them; and even if 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

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* Deluc *sur la Meteorol.* ii. 100.

Chap. II.

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 was 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 the 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: and if Dr Watson's experiment formerly mentioned be attended to, it will not be objected that the quantity of evaporation is also very much diminished. Of the very dry state to which the atmosphere is reduced during long droughts, the violent thunder-storms with which 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 from which it was evaporated, otherwise the whole atmosphere would in a much less period than a month be perfectly saturated with moisture. If it be carried up daily through the different strata of the atmosphere, and wafted to other regions by superior currents of air, how is it possible to account for the different electrical state of the clouds situated between different strata, which often produces the most violent thunder-storms? Are not vapours conductors of the electric fluid? and would they not have daily restored the equilibrium of the whole atmosphere through which they passed? Had they traversed the atmosphere in this manner, there

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* *Asiatic Researches*, vol. ii. Appendix.

would have been no negative and positive clouds, and consequently no thunder-storms. They could not have remained in the lower strata of the atmosphere, and been daily carried off by winds to other countries; for there are often no winds at all during several days to perform this office; nor in that case would the dews diminish, nor could their presence fail to be indicated by the hygrometer.

It is impossible for us to account for this remarkable fact upon any principle with which we are acquainted. The water can neither remain in the atmosphere, nor pass through it in the state of vapour. It must therefore assume some other form; but what that form is, or how it assumes it, we know not.

There are, then, two steps of the process between evaporation and rain, of which at present we are completely ignorant: 1. What becomes of the vapour after it enters into the atmosphere. 2. What makes it lay aside the new form which it must have assumed, and return again to its state of vapour, and fall down in rain. And till these two steps be discovered by experiments and observations, it will be impossible for us to give a rational or a useful theory of rain.

Dr Pratt of Exeter has endeavoured to prove, in a very ingenious treatise, that water is decomposed during its evaporation, and converted into oxygen and hydrogen 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 azote 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, azote, 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	00	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 than in summer; but the quantity of rain is greater in summer than in winter [**]. At Petersburgh the number of rainy or snowy days during winter is 84, and the

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[*] Cotte, *Jour. de Phys.* Oct. 1791, p. 264.

[†] *Asiatic Researches*, i. and ii. Appendix.

[‡] Cotte, *Jour. de Phys.* Oct. 1791, p. 264.

[§] *Phil. Trans.*

[‖] *Edin. Trans.* ii. 244.

[¶] Cotte, *Jour. de Phys.* Oct. 1791, p. 264.

[**] Id. Ibid.

quantity which falls is only about five inches; during summer the number of rainy days is nearly the same, but the quantity which falls is about 11 inches *.

More rain falls in mountainous countries than in plains. Among the Andes it is said to rain almost perpetually, while in Egypt it hardly ever rains at all. If a rain-gauge be placed on the ground, and another at some height perpendicularly above it, more rain will be collected into the lower than into the higher; a proof that the quantity of rain increases as it descends, owing perhaps to the drops attracting vapour during their passage through the lower strata of the atmosphere, where the greatest quantity resides. This, however, is not always the case, as Mr Copland of Dumfries discovered in the course of his experiments †. He observed, also, that when the quantity of rain collected in the lower gauge was greatest, the rain commonly continued for some time; and that the greatest quantity was collected in the higher gauge only either at the end of great rains, or during rains which did not last long. These observations are important, and may, if followed out, give us new knowledge of the causes of rain. They seem to show, that during rain the atmosphere is somehow or other brought into a state which induces it to part with its moisture; and that the rain continues as long as this state continues. Were a sufficient number of observations made on this subject in different 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.

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* *Edin. Trans.* ii. 244.

† *Manchester Trans.* iv. 619.

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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.

The dry land amounts to 52,745,253 square miles; the quantity of rain falling on it annually therefore will amount to 30,960 cubic miles. The quantity of water running annually into the sea is 13,140 cubic miles; a quantity of water equal to which must be supplied by evaporation from the sea, otherwise the land would soon be completely drained of its moisture.

The quantity of rain falling annually in Great Britain may be seen from the following TABLE:

Years of observation.	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	Branxholm, 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

Mr Dalton, in an ingenious essay on this subject, estimates the quantity of rain for England at 31 inches††; but as we have no observations kept in Wales or the Highlands of Scotland, where much rain falls, it cannot be doubted that the proportion for Britain must exceed that sum.

In this country it generally rains less in March than in November, in the proportion at a medium of seven to 12. It generally rains less in April than October, in

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* *Manchester Trans.* iv.

† *Phil. Trans.* Tables of Observations.

‡ Ibid. vol. lxxix. part I.

§ Mr Barker, Ibid.

‖ *Edin. Trans.* i. 208.

¶ *Statist. Account of Scotland*, v. 245.

** *Edin. Trans.* i. 333.

†† *Manchester Memoirs*, v. 349.

the proportion of one to two nearly at a medium. It generally rains less in May than September; the chances that it does so are at least as four to three: 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 faculties, philosophers have not made that progress in it

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[*] Kirwan, *Irish Trans.* v. 21.

which the sanguine imaginations of some individuals led them to expect. Many discoveries indeed have been made; and from the numbers and the genius of the philosophers at present engaged in this study, others equally important may be expected. But, notwithstanding this, many of the phenomena remain unexplained, and a rational and satisfactory theory seems still beyond our reach. I shall in this Section give as complete a detail as possible of the natural history of the winds in the different parts of the world, and then consider how they may be explained.

1. Winds in the torrid zone.

As the winds are much more regular between the tropics than in the temperate zones, it will be proper in the first place to begin with them.

Trade-wind.

In those parts of the Atlantic and Pacific Oceans which lie nearest the equator, there is a regular wind during the whole year called the *trade-wind*. On the north side of the equator it blows from the north-east, varying frequently a point or two towards the north or east; and on the south side of it, from the south-east; changing sometimes in the same manner towards the south or east. The space included between the second and fifth degree of north latitude is the internal limit of these two winds. There the winds can neither be said to blow from the north nor the south; calms are frequent, and violent storms. This space varies a little in latitude as the sun approaches either of the tropics.—In the Atlantic Ocean the trade-winds extend farther north on the American than on the African coast; and as we advance westward, they become gradually more easterly, 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

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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. p. 136.

summer months, approaching gradually to the south-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-

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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. 156.

§ Dr Halley, Ibid.

|| Bruce's *Travels*, vol. i. ch. 4.

west *. The bay of Panama is the only place on the west side of a great continent where the wind shifts 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 degrees 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

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* Sir Walter Raleigh's *Voyage*. Forest's *Voyage*, p. 97.

† Dr Halley, *Phil. Trans.* Abr. vol. ii. p. 136.

‡ Sir Walter Raleigh's *Voyage*.—Dr Garden, *Phil. Trans.* Abr. vol. ii. p. 132.

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 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,

Balama.

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* Marsden's *Hist. of Sumatra*, p. 17.—Buffon's *Nat. Hist.* vol. i. p. 385.

† Volney's *Travels*.

‡ Pontoppidan's *Natural History of Norway*.

§ Dr Schotte, *Phil. Trans.* vol. lxx. art. 25.

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 *.

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 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 ‡.

Fezzan,

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

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* P. Beaver, Esq. See Map in Wadstrom's *Essay on Colonization.*

† *African Association*, p. 200. ‡ Ibid.

§ Bruce's *Travels*, vol. iv. p. 651.

‖ *Asiatic Researches*, vols i. and ii. Append.

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 in the same degree of latitude we find them often blowing in different directions at the same time; while their changes are frequently so sudden and so capricious, that to account for them has hitherto been found impossible. When winds are violent, and continue long, they generally extend over a large tract of country: and this is more certainly the case when they blow from the north or east than from any other points [†]. By the multiplication and comparison of Meteorological Tables, some regular connection between the changes of the atmosphere in different places may in time be observed, which will at last lead to a satisfactory theory of the winds. It is from such tables chiefly that 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 in 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 be-

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[*] P. Cotte, *Jour. de Phys.* 1791.

[†] Derham's *Physico-Theology*, ch. ii.

[‡] Jefferson's *Virginia*, p. 123.—*Trans. Philad.* ii. art. 10.

tween the south-west, west, north, and north-east; the most frequent is the north-west [*]. But at Cambridge, in 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 Canada; 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

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[*] *Trans. Amer. Acad.* i. 336.

[†] M. Cotte, *Jour. de Phys.* 1791.

[‡] Ibid.

[§] *Present State of Nova Scotia and Canada*, p. 38.

[||] Cotte, *Jour. de Phys.* 1791.

[¶] Pennant's *Suppl. to Arctic Zool.* p. 41.

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 autumn †. These observations do not apply to the Gut of Gibraltar, where there are seldom any winds except the east and the west. At Bastia, in the island of Corsica, the prevailing wind is the south-west ‡.

Asia.

In Syria the north wind blows from the autumnal equinox to November; during December, January, and February, the winds blow from the west and south-west; in March they blow from the south, in May from the east, and in June from the north. From this month to the autumnal equinox the wind changes gradually as the sun approaches the equator; first to the east, then to the south, and lastly to the west §. At Bagdad the most frequent winds are the south-west and north-west; at Pekin, the north and the south ||; at Kamtschatka, on the north-east coast of Asia, the prevailing winds blow from the west ¶.

South of Europe,

In Italy the prevailing winds differ considerably according to the situation of the places where the observations have been made: At Rome and Padua they are

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* Volney's *Travels*, i. 58.

† Ibid. i. 59 and 65.

‡ Cotte, *Jour. de Phys.* 1791.

§ Volney's *Travels*, i. 326.

|| Cotte, Ibid.

¶ Pennant's *Arctic Zool.* p. cxiii.

northerly, at Milan easterly *. All that we have been able to learn concerning Spain and Portugal is, that on the west coast of these countries the west is by far the most common wind, particularly in summer; and that at Madrid the wind is north-east for the greatest part of the summer, blowing almost constantly from the Pyrenean mountains †. At Berne in Switzerland the prevailing winds are the north and west; at St Gottard, 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 six; the north-east in four; the south-east in two; 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 Hamburg, 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 ‡.

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* Cotte, *Jour. de Phys.* 1791.

† Bohun's *Hist. of Winds*, p. 116.

‡ Cotte, *Jour. de Phys.* 1791.

Germany,

In Germany the east wind is most frequent at Gottingen, Munich, Wiessemburgh, Dusseldorf, Saganum, 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:

Winds.	Days.	Winds.	Days.
South-west	112	South-east	32
North-east	58	East	26
North-west	50	South	18
West	53	North	16

It appears from the same register, that the south-west wind blows at an average more frequently than any other wind during every month of the year, and that it blows longest in July and August; that the north-east blows most constantly during January, March, April, May, and June, and most seldom during February, July, September, and December; and that the North-west wind blows oftener from November to March, and more seldom during September and October than any other months. The south-west winds are also most frequent at Bristol, and next to them are the north-east †.

The following TABLE of the winds at Lancaster has been drawn up from a register kept for seven years at that place ‡.

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* Cotte, *Jour. de Phys.* 1791.

† *Phil. Trans.* lxvi. 2.

‡ *Manchester Transactions*, iv. 234.

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Winds.	Days.	Winds.	Days.
South-west	92	South-east	35
North-east	67	North	30
South	51	North-west	26
West	47	East	17

The following Table is an abstract of nine years observations made at Dumfries by Mr Copland *.

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	40	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 Ayrshire, 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

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[*] *Manchester Transactions*, iv. 234.

[†] *Statistical Account of Scotland*, v. 245.

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.

Years of Observ.	Places.	Wind.	
		Westerly.	Easterly.
10	London	233	132
7	Lancaster	216	149
51	Liverpool *	190	175
9	Dumfries	227·5	137·5
10	Branxholm, 44 miles south-west of Berwick † . . .	232	133
7	Cambuslang	214	151
8	Hawkhill, near Edinburgh ‡	229·5	135·5
	Mean	220·3	144·7

Ireland,

In Ireland the south-west and west are the grand trade-winds, blowing most in summer, autumn, and winter, and least in spring. The north-east blows most in spring, and nearly double to what it does in autumn and winter. The south-east and north-west are nearly equal, and are most frequent after the south-west and west §.

North of Europe.

At Copenhagen the prevailing winds are the east and south-east; at Stockholm, the west aud north ||.

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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.

In Russia, from an average of a register of 16 years, the winds blow from November to April in the following order:

	W.	N.W.	E.	S.W.	S.	N.E.	N.	S.E.
Days	45	26	23	22	20	19	14	12

And during the other six months,

	W.	N.W.	E.	S.W.	S.	N.E.	N.	S.E.
Days	27	27	19	24	22	15	32	18

The west wind blows during the whole year 72 days; the north-west 53; the south-west and north 56 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.

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[*] Guthrie on the Climate of Russia, *Edin. Trans.* ii.

[†] Pontoppidan's *Nat. Hist. of Norway*, part i.

M. de la Caille, 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, and tempests, and hurricanes. Between the Cape of Good Hope and New Holland the winds are commonly westerly, and blow in the following order: north-west, south-west, west, north *.

In the Great South Sea, from latitude 30° to 40° south, the south-east trade-wind blows most frequently, especially when the sun approaches the tropic of Capricorn; the wind next to it in frequency is the north-west, and next to that is the south-west. From south latitude 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 it is the west †.

Thus it appears that the trade winds sometimes extend 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 direc-

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* Meteorological Tables at the end of Philip's and White's *Voyages.*

† Wale's *Meteor. Tables.*

tion 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 hurricane 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 by 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. The following Table, drawn up by Mr Smeaton, will give the reader a pretty precise idea of the velocity of the wind in different circumstances *.

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* *Phil. Trans.* 1759, p. 165.

Miles per Hour.	Feet per Second.	Perpendicular Force on one square Foot, in Avoirdupois Pounds and Parts.	
1	1·47	·005	Hardly perceptible
2	2·93	·020	Just perceptible
3	4·4	·044	
4	5·87	·079	Gently pleasant
5	7·33	·123	
10	14·67	·492	Pleasant, brisk
15	22·	1·107	
20	29·34	1·968	Very brisk
25	36·67	3·075	
30	44·01	4·429	High wind
35	51·34	6·027	
40	58·68	7·873	Very high wind
45	66·01	9·963	
50	73·35	12·300	Storm or tempest
60	88·02	17·715	Great storm
80	117·36	31·490	Hurricane
100	146·7	49·200	Hurricane that tears up trees and carries buildings before it.

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 $11\frac{1}{2}$ 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° to the equator, it would not immediately acquire the velocity of the equator; the eminences of the earth therefore would strike against it, and it would assume the appearance of an east wind. This is the case in a smaller degree with the air that flows towards the equator, to supply the place of the rarefied air, which is continually ascending; and this, when combined with its real motion from the north and south, must cause it to assume the appearance of a north-easterly wind on this side the equator, and of a south easterly beyond it *.

The motion westwards occasioned by this difference in celerity alone would scarcely be perceptible; but it is much increased by another circumstance. Since the rarefaction of the air in the torrid zone is owing to the heat derived from the contiguous earth, and since this heat is owing to the perpendicular rays of the sun, those parts must be hottest where the sun is actually vertical, and consequently the air over them must be most rarefied; the contiguous parts of the atmosphere will therefore be drawn most forcibly to that particular spot. Now since the diurnal motion of the sun is from east

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* This cause of the trade-winds was first assigned by Hadley in 1734. See *Phil. Trans. Abridg.* viii. 500.

to west, this hottest spot will be continually shifting westwards, and this will occasion a current of the atmosphere in that direction. That this cause really operates, appears from a circumstance already mentioned: When the sun approaches either of the tropics, the trade-wind on the same side of the equator assumes a more easterly direction, evidently from the cause here mentioned; while the opposite trade-wind, being deprived of this additional impulse, blows in a direction more perpendicular to the equator *.

The westerly direction of the trade-winds is still farther increased by another cause. Since the attraction 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

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* This cause was first assigned by Dr Halley in his essay on the trade-winds; and is certainly by far the most powerful of all the agents.

† This cause was first assigned by D'Alembert in his dissertation *on the Cause of the Winds.*

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 contrary would take place. We have seen, however, that though this boundary be subject to considerable changes from this very cause, it may in general be considered as fixed between the second and fifth degrees of north latitude.

Though the sun be perpendicular to each of the tropics during part of the year, he is for one half of it at a considerable distance; so that the heat which they acquire while he is present is more than lost during his absence. But the sun is perpendicular to the equator twice in a year, and never farther distant from it than $23\frac{1}{2}°$: being therefore twice every year as much heated, and never so much cooled as the tropics, its mean heat must be greater, and the atmosphere in consequence generally most rarefied at that place. Why then, it will be asked, is not the equator the boundary of the two trade-winds? To speak more accurately than we have hitherto done, the internal limit of these winds must be that 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 shown by astronomers, that the orbit of the earth is an ellipsis, and the sun is placed in one of the foci. Were this orbit to be divided into two parts by a straight line perpendicular to the transverse axis, and passing through the centre of the sun, one of these 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 seven 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 summer in the northern hemisphere consists of 186 days 11 hours and 37 minutes, while in the southern it is only 178 days 18 hours and 11 minutes. They are to one another nearly in the proportion of 15 to 14·3; 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 the two hemispheres is not great, the parallel ought not be far distant from the equator.

Causes of the monsoons.

The trade-wind would blow regularly round the whole globe if the torrid zone were all covered with water. If the Indian Ocean were not bounded by land on the north, it would blow there in the same manner as it does in the Atlantic and Pacific Oceans. Land is much more opaque than water; it becomes therefore much warmer when both are equally exposed to the influence 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 3d to the 10th 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 Africa and America. The air above the land is hotter and rarer, and consequently lighter, than the air above the sea; the sea air therefore flows in, and forces the lighter land atmosphere to ascend.

And of the sea and land breezes.

The same thing will account for the phenomena of the sea and land breezes. During the day, the cool air of the sea, loaded with vapours, flows in upon the land, and takes the place of the rarefied land air. As the sun declines the rarefaction of the land air is diminished: thus an equilibrium is restored. As the sea is not so much heated during the day as the land, neither is it so much cooled during the night; because it is constantly exposing a new surface to the atmosphere. As the night approaches, therefore, the cooler and denser air of the hills (for where there are no hills there are no sea and land breezes) falls down upon the plains, and, pressing upon the now comparatively lighter air of the sea, causes the land-breeze.

The rarefied air which ascends between the second and fifth degrees of north latitude has been shown to be the principal cause of the trade-winds. As this air ascends it must become gradually colder and consequently heavier; it would therefore descend again if it were not buoyed up by the constant ascent of new rarefied air. It must therefore spread itself to the north and south, and gradually mix in its passage with the lower air; and the greater part of it probably does not reach far beyond the 30°, which is the external limit of the trade-wind. Thus there is a constant circulation of the atmosphere in the torrid zone; it ascends near the equator, diffuses itself towards the north and south, descends gradually as it approaches the 30°, and returning again towards the equator performs the same circuit.

Cause of south-west winds.

If the attraction of the moon and the diurnal motion 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.

Mr Kirwan has rendered it probable that the frequency of south-west winds in our latitudes, at least during winter, is owing to an opposite current, which blows in the eastern parts of our hemisphere, between the coast of Malabar and the Moluccas during the same season. This northern wind must be supplied from countries still farther north to the pole, which must be recruited in its turn from the countries to the south of it in the western parts of our hemisphere *.

Our theory of the variable winds is still too imperfect to attempt any thing like a satisfactory explanation of them. They evidently stamp the nature of every climate, and therefore depend upon causes which act with uniformity, notwithstanding all their apparent irregularity. They are all intimately connected with each other, and probably succeed each other in a certain order, though that order has not hitherto been observed. All that can be done at present is to offer a few unconnected remarks.

Winds appear usually to begin at that point towards which they blow †. They must therefore be owing to a rarefaction or displacing of the air in some particular quarter, either by the action of heat or some other cause. This is more particularly the case when the wind blows with violence. Hurricanes are uniformly preceded by a great fall of the barometer: and the wind often flows in every direction towards the place where the barometer stands so low. One would be tempted in this case to suppose the sudden decomposition of a portion of the atmosphere. Strong north-east winds have been repeatedly observed beginning at the quarter towards which they flow. In 1740 Dr Franklin 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 11 o'clock: and upon comparing all the accounts which he received from the several colonies of the beginning of

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* *Irish Trans.* viii. 400.

† Kirwan, Ibid. p. 397.

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 successive current is formed, to which our coast and inland mountains give a north-east direction.*"

A similar storm was observed by Dr Mitchell in 1802. It began at Charlestown on the 21st February, at two o'clock in the afternoon; at Washington, which lies several hundred miles to the north-east, it was not observed till five o'clock; at New York it began at ten in the evening; and at Albany not till day-break of the 22d. Its motion, from this statement, was 1100 miles in 11 hours, or 100 miles in the hour†.

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* Franklin's *Philosophical Letters*, p. 389.

† *Phil. Mag.* xiii. 272.

A remarkable storm of the same kind, and accompanied by an easterly wind, was observed in Scotland on the 8th of February 1799. It was attended by a very heavy fall of snow, and the motion of the wind was much slower. At Falkirk it began to snow at six in the evening of the 7th; at Edinburgh at about one o'clock in the morning of the 8th; and at Dunbar at eight o'clock in the morning. It lasted 11 hours, and did not travel above 100 miles during that time.

The north-east wind blows most frequently with us during the spring months; and from the observations made by Captain Cooke, it appears that the same wind prevails during the same period in the Northern Pacific. Hence it appears that at that season the cold air from the north of Europe and America flows into the Atlantic and Pacific. Hence the reason of its uncommon coldness, dryness, and density.

It is very common to observe one current of air blowing at the surface of the earth, while a current flows in a contrary direction in the higher strata of the atmosphere. On one occasion I even observed three such winds blowing in contrary directions all at the same time. It is affirmed that changes of weather generally begin in the upper strata of the air; the wind which blows there gradually extending itself to the surface of the earth *.

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,

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* Derham and Gentil.—Kirwan, *Irish Trans.* viii. 404.

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 mixing with the atmosphere. Partial voids, therefore, and partial accumulations, must be continually taking place in different parts of the atmosphere, which will occasion winds varying in direction, violence, and continuance, according to the suddenness and the quantity of air destroyed or produced. Besides these there are many other ingredients constantly mixing with the atmosphere, and many partial causes of condensation and rarefaction in particular places. To these, and other causes probably hitherto unknown, are to be ascribed all those winds which blow in any place besides the general ones already explained; and which, as they depend on causes hitherto at least reckoned contingent, will probably for ever prevent uniformity and regularity in the winds. All these causes, however, may, and probably will, be discovered; the circumstances in which they will take place, and the effects which they will produce, may be known; and whenever this is the case, 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

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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 state of its electricity is changed by various chemical operations which often go on in the atmosphere. Evaporation seems in all cases to convey electric matter into the atmosphere; and Saussure has ascertained, that the quantity of electricity is much increased when water is decomposed, as when water is dropt on a red hot iron. On the other hand, when steam is condensed into vesicular vapour, or into water, the air becomes negatively electric. Hence it would seem that electricity enters as a component part into water; that it separates when water is decomposed or expanded into steam, and is reunited when the steam is condensed again into water.

Farther, Mr Canton has ascertained that dry air, when heated, becomes negatively electric, and positive when cooled, even when it is not permitted to expand or contract: and the expansion and contraction of air also occasion changes in its electric state.

Sources of it.

Thus there are four sources of atmospheric electricity known: 1. Friction; 2. Evaporation; 3. Heat and cold; 4. Expansion and contraction: not to mention the electricity evolved by the melting, freezing, solution, &c. of various bodies in contact with air.

Consequences of its accumulation.

7. As air is an electric, the matter of electricity, when accumulated in any particular strata, will not immediately make its way to the neighbouring strata, but will induce in them changes similar to what is indu-

ced upon plates of glass or similar bodies piled upon each other. Therefore if a stratum of air be electrified positively, the stratum immediately above it will be negative, the stratum above that positive, and so on. Suppose 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 when electricity is discharged in a vacuum. What the change is which electricity produces in air, or how it produces it, are questions which, in the present state of our knowledge, are altogether insoluble. But the very extraordinary galvanic phenomena which at present occupy the attention of philosophers, promise not only to throw light upon this important subject, but to demonstrate a much closer connection between chemistry and electricity than has hitherto been suspected.

SECT. VI.

OF THE STONES WHICH FALL FROM THE ATMOSPHERE.

History.

NOTHING can be a more complete proof of the imperfect state of the science of Meteorology, than the discovery of facts, for which not even a conjectural cause in the smallest degree probable can be assigned. Luminous bodies called *meteors, fire-balls,* &c. have in all ages been observed in the atmosphere, and many of them have been described by eye-witnesses. One of the most remarkable of these was the meteor which appeared in 1783. It was very luminous, and its diameter could not be less than 1000 yards. It traversed Britain and a considerable part of the continent of Europe with very great velocity, and at the height of nearly 60 miles from the surface of the earth[*]. Almost all the meteors observed resembled each other. They were luminous, at a great height, moved very swiftly, and disappeared in a very short time. Their disappearance was usually accompanied by a loud explosion like a clap of thunder; and it was almost constantly affirmed, that heavy stony bodies fell from them to the earth. But though several well authenticated accounts of the fall of such stones had been from time to time published, little credit was given to them; nor did they indeed attract the attention of philosophers, till Dr Chladni published a dissertation on the subject in 1794. Two years after Mr King published a still more complete collection of examples, both ancient and modern; many of them supported by such evidence that it was impossible to reject it. These two dissertations excited considerable attention: but the opinion, that stones had really fallen from the atmosphere, was considered as so extraordinary, and so contrary to what we know of the constitution of the air, that most people hesitated or refused their assent. Meanwhile Mr Howard took a different method of investigating the subject. He not only collected all the recent and well authenticated accounts of the fall of stony bodies, and examined the evidence of their truth, but procured specimens of the stones which were said to have fallen in different places, compared them together, and subjected them to a chemical analysis. The result was, that all these stony bodies differ completely from every other known stone; that they

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[*] See Cavallo's description of it, *Phil. Trans.* 1784.

all resemble each other, and that they are all composed of the same ingredients. His dissertation on the subject was published in the Philosophical Transactions for 1802. The proofs which this admirable dissertation contains, that the stony bodies in question really fell from the atmosphere, are quite irresistible. Indeed their external characters and chemical analysis would alone decide the point: For it is quite inconceivable that in India, England, France, Germany, and Italy, in climates and in soils exceedingly different from each other, stones should have been pointed out which differed from every other mineral in the countries where they were found, and which exactly resembled one another, provided these had not had the same origin. The chemical analysis of Howard was soon after repeated and verified by Vauquelin * and Klaproth †.

Table of the best authenticated instances of the fall of stones.

1. Most of the stones which have fallen from the atmosphere have been preceded by the appearance of luminous bodies or meteors. These meteors burst with an explosion, and then the shower of stones falls to the earth. Sometimes the stones continue luminous till they sink into the earth; but most commonly their luminousness disappears at the time of the explosion. These meteors move in a direction nearly horizontal, and they seem to approach the earth before they explode. The following Table, drawn up by Mr Izarn, exhibits a collection of the best authenticated instances of the falling of stones from the atmosphere hitherto observed, together with the time when they fell, and the persons on whose evidence the fact rests ‡.

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* *Ann. de Chim.* xlv. 225. † *Phil. Mag.* xv. 182. ‡ Ibid. xvi. 298.

Substances.	*Places where they fell.*	*Period of their Fall.*	*Testimony.*
Shower of stones	At Rome	Under Tullus Hostilius	Livy
Shower of stones	At Rome	Consuls C. Martius and M. Torquatus	J. Obsequens
Shower of iron	In Lucania	Year before the defeat of Crassus	Pliny
Shower of mercury	In Italy		Dion
A very large stone	Near the river Negos, Thrace	Second year of the 78th Olympiad	Pliny
Three large stones	In Thrace	Year before J C 452	Ch. of Court Marcellin
Shower of fire	At Quesnoy	January 4th, 1717	Geoffroy le Cadet
Stone of 72 lbs.	Near Larissa, Macedonia	January 1706	Paul Lucas
About 1200 stones—one of 120 lbs.	Near Padua in Italy	In 1510	Carden, Varcit
Another of 60 lbs.			
Another of 59 lbs.	On Mount Vasier, Provence	November 27th, 1627	Gassendi
Shower of sand for 15 hours	In the Atlantic	April 6th, 1719	Pere la Feuillée
Shower of sulphur	Sodom and Gomorra		Moses
Sulphureous rain	In the Duchy of Mansfield	In 1658	Spangenberg
The same	Copenhagen	In 1646	Olaus Wurmius
Shower of sulphur	Brunswick	October 1721	Siegesber
Ditto of a viscid unknown matter	Ireland	In 1695	Muschenbroeck
Two large stones weighing 20 lbs.	Liponas in Bresse	September 1753	Delalande
A stony mass	Niort, Normandy	In 1750	Delalande
A stone of 7½ lbs.	At Luce in Le Maine	September 13th, 1768	Bachelay
A stone	At Aire in Artois	In 1768	Gurson de Boyaval
A stone	In Le Cotentin	In 1768	Morand
Extensive shower of stones	Environs of Agen	July 24th, 1790	St Amand, Baudin, &c.
About 12 stones	Sienna, Tuscany	July 1794	Earl of Bristol
A large stone of 56 lbs.	Wold-Cottage, Yorkshire	December 13th, 1795	Captain Topham
A stone of about 20 lbs.	Salé, Department of the Rhone	March 17th, 1798	Lelievre and De Drée
A stone of 10 lbs.	In Portugal	February 19th, 1796	Southey
Shower of stones	Benares, East Indies	December 19th, 1798	J. Lloyd Williams, Esq.
Shower of stones	At Plann, near Tabor, Bohemia	July 3d, 1753	B. de Born
Mass of iron 70 cubic feet	America	April 5th, 1800	Philosophical Magazine
Mass of ditto, 14 quintals	Abakank, Siberia	Very old	Pallas, Chladni, &c.
Shower of stones	Barboutan, near Roquefort	July 1789	Darcet, jun. Lomet, &c.
Large stone 260 lbs.	Ensisheim, Upper Rhine	November 7th, 1492	Butenschoen
Two stones 200 and 300 lbs.	Near Verona	In 1762	Acad. de Bourd.
A stone of 20 lbs.	Sales, near Ville-Franche	March 12th, 1798	De Drée
Several ditto from 10 to 17 lbs.	Near L'Aigle, Normandy	April 26th, 1803	Fourcroy

Stones usually covered with a black crust.

2. The stony bodies when found are always hot. They commonly bury themselves some depth under ground. Their size differs from a few ounces to several tons. They are usually roundish, and always covered with a black crust. In many cases they smell strongly of sulphur. The black crust, from the analysis of Howard, consists chiefly of oxide of iron.

Their composition.

3. The outer surface of these stones is rough. When broken, they appear of an ash-grey colour, and of a granular texture like a coarse sandstone. When examined with a microscope, four different substances may be discovered of which the stone is composed: 1st, A number of spherical bodies, varying in size from a pin-head to a pea of a greyish-brown colour, opaque, breaking easily in every direction, of a compact texture, capable of scratching glass, and of giving a few feeble sparks with steel. 2d, Fragments of pyrites of an indeterminate shape, of a reddish-yellow colour, granular, and easily reduced to powder. The powder has a black colour. 3d, Grains of iron in the metallic state, scattered like the pyrites through the stone. 4th, The three substances just mentioned are cemented together by a fourth of an earthy consistence, and so soft that all the other substances may be easily separated by the point of a knife or the nail, and the stone itself crumbled to pieces between the fingers. This cement is of a grey colour[*]. The proportion and size of these different constituents vary considerably in different specimens; but all of them bear a striking resemblance to each other. Their specific gravity varies from 3·352 to 4·281[†].

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[*] Bournon, *Phil. Trans.* 1802.

[†] Ibid.

Their chemical analysis.

4. From the analysis of Howard, which was conducted with much precision and address, and which has been fully confirmed by Vauquelin and Klaproth, we learn that the black crust consists of a compound of iron and nickel, partly metallic, and partly oxidized. The pyrites consist of iron, nickel, and sulphur. The metallic grains consist of iron, combined with about $\frac{1}{3}$d of its weight of nickel, and the yellow globules are composed of silica, magnesia, iron, and nickel. The Count Bournon observes, that these globules resemble the chrysolite of Werner, and that their chemical analysis corresponds exactly with Klaproth's analysis of that mineral. The earthy cement consists of the very same substances, and nearly in the same proportions as the globular substances. But it will be necessary to exhibit a specimen of some of the analyses, as published by the philosophers to whom we are indebted for them. A stone which fell at Benares in India was analysed by Howard. The pyrites consisted of

2·0	sulphur
10·5	iron
1·0	nickel
2·0	earths and foreign bodies
15·5	

The spherical bodies	50·0	silica
	15·0	magnesia
	34·0	oxide of iron
	2·5	oxide of nickel
	101·5	

The earthy cement 48·0 silica
18·0 magnesia
34·0 oxide of iron
2·5 oxide of nickel

102·5

A stone which fell in Yorkshire, deprived as much as possible of its metallic particles, gave Mr Howard from 150 grains.........75 silica
37 magnesia
48 oxide of iron
2 oxide of nickel

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The increase of weight was owing to the oxidizement of the metallic bodies.

Stones which fell at Laigle in France in 1803 yielded, by the analyses of Vauquelin and Fourcroy,
54 silica
36 oxide of iron
9 magnesia
3 oxide of nickel
2 sulphur
1 lime

105*

The following Table exhibits the result of the most remarkable analyses of such stones, which have been made since the publication of Howard's paper on the subject.

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* *Phil. Mag.* xvi. 302.

	*	†	‡	‖	§
Iron		2·25	19·0	38·3	17 to 22
Nickel	2·4	0·60	1·5	0·33	
Oxide of iron . .	30·0	25·00	16·5		5
Sulphuret of iron					12
Sulphur	3·5	Trace	Trace	9·00	
Silica	56·0	44·00	37·0	34·00	
Magnesia	12·0	22·50	21·5	14·50	66
Lime	1·4				Trace
Manganese. . . .		0·25		0·83	

Conjectures respecting their origin.

5. The experiments of Howard, thus confirmed by others, and supported by the most respectable historical evidence, having demonstrated that these stony bodies really do fall from the heavens, it was natural to expect that various attempts would be made to account for their appearance. But such is the obscurity of the subject, so little progress have we made in the science of meteorology, that no opinion in the slightest degree probable has hitherto been advanced. It was first supposed that the bodies in question had been thrown out of volcanoes; but the immense distance from all volcanoes at which they have been found, and the absence of all similar stones from volcanic productions, render this opinion untenable. Chladni endeavoured to prove that the meteors from which they fell were bodies float-

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* Vauquelin, *Phil. Mag.* xvi. 302. The stone fell at Ensisheim in 1492.

† Klaproth, Gehlen's *Jour.* i. 8. The stone fell at Siena in 1794.

‡ Klaproth, Ibid. p. 12. The stone fell at Auchstadtschen in Germany.

‖ Laugier, Ibid. iv. 531. The stone fell at Vaucluse in 1804. See a description of it by Vauquelin, *Ann. de Chim.* xlviii. 225.

§ Proust, *Jour. de Phys.* lx. 185. The Stone fell at Sigena in 1773.

ing in space, unconnected with any planetary system, attracted by the earth in their progress, and kindled by their rapid motion through the atmosphere. But this opinion is not susceptible of any direct evidence, and can scarcely be believed, one would think, even by Dr Chladni himself. Laplace suggests the probability of their having been thrown off by the volcanoes of the moon: But the meteors which almost always accompany them, and the swiftness of their horizontal motion, militate too strongly against this opinion. The greater number of philosophers consider them, with Mr King and Sir William Hamilton, as concretions actually formed in the atmosphere. This opinion is undoutedly the most probable of all ; but in the present state of our knowledge, it would be absurd to attempt any explanation of the manner in which they are formed. The masses of native iron found in South America, in Siberia, and near Agnam, contain nickel, as has been ascertained by Proust, Howard, and Klaproth, and resemble exactly the iron found in the stones fallen from the atmosphere. We have every reason therefore to ascribe to them the same original: and this accordingly is almost the uniform opinion of philosophers. Klaproth has shown that real native iron is distinguished from meteoric iron by the absence of nickel *.

Upon the whole, we may consider these stony and metallic masses as fragments of fire-balls which have burst in the atmosphere ; but the origin and cause of these fire-balls will perhaps for ages baffle all the attempts of philosophers to explain them.

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* Gehlen's *Jour.* i. 8.

BOOK II.

OF

WATERS.

Book II.
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 iufluence 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

Divisible into three classes.

very conveniently divided into three classes: 1. Waters which may be used for dressing food, and the other purposes of domestic economy to which water is usually applied. These, for want of a better name, may be called *common water*. 2. Sea water. 3. Those waters which have been called *mineral*, in consequence of the notable quantity of mineral substances which they contain.—These three classes of waters shall form the subject of the three following Chapters.

Book II.

CHAP. I.

OF COMMON WATERS.

Good water is as transparent as crystal, and entirely colourless. It has no smell, and scarcely any taste; and in general the lighter it is so much the better. If we compare the different waters which are used for the common purposes of life with each other, and judge of them by the above standard, we shall find them to differ considerably from each other, according to the circumstances of their situation. These waters may be reduced under four heads; namely, 1. Rain water; 2. Spring and river water; 3. Well water; 4. Lake water.

Rain water.

1. Rain water, unless when near a town or when collected at the commencement of the rain, possesses the properties of good water in perfection, and is as free from foreign ingredients as any native water whatever. The substances which it holds in solution are *air*, *carbonic acid*, *carbonate of lime*, and, according to Bergman, it yields some traces of *nitric acid*, and a little *muriate of lime*[*]. The existence of air in water was first pointed out by Boyle. Scheele first observed that this air contained a greater proportion of oxygen than common air. The quantity of air in good water does not exceed $\frac{1}{28}$th of the bulk. One hundred cubic inches

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[*] Bergman, i. 87.

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.

Snow water.

How purified.

The quantity of muriate of lime contained in rain water must be exceedingly minute; provided Morveau's assertion, 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, be well founded. According to this philosopher, the rain water which drops from the roofs of houses, after it has rained for some time, contains only a little sulphate of lime, which it has dissolved as it trickled over the slates ‡.

If meteoric stones be really formed in the atmosphere, we have reason to expect a greater proportion of foreign bodies in rain water at some seasons than others. It is not unlikely that some light might be thrown upon the decompositions going on in the atmosphere, by examining the solid substances left behind when rain water is evaporated.

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* Bergman, i. 87.

† *Jour. de Phys.* xlviii. 226.

‡ *Ann. de Chim.* xxiv. 321.

Spring water.

2. The water of springs is nothing else than rain water, which, gradually filtering through the earth, collects at the bottom of declivities, and makes its way to the surface. It is therefore equally pure with rain water, provided it does not meet with some soluble body or other in its passage through the soil. But as this is almost always the case, we generally find, even in the purest spring water, a little carbonate of lime and common salt, besides the usual proportion of air and carbonic acid gas. Sometimes also it contains muriate of lime or a little carbonate of soda *. Dr Henry expelled the air from a portion of spring water by boiling; 100 cubic inches of the water yielded 4·76 inches of gas. This gas he found a mixture of 3·38 inches of carbonic acid, and 1·38 of atmospherical air †. Bergman found the springs about Upsal, which are reckoned exceedingly pure, to contain the following foreign bodies:

1. Oxygen gas,
2. Carbonic acid,
3. Carbonate of lime,
4. Silica,
5. Common salt,
6. Sulphate of potash,
7. Carbonate of soda,
8. Muriate of lime.

The whole of these ingredients amounted at an average to 0·00004 parts; and the proportion of each of the solid bodies was as follows:

Carbonate of lime	5·0	Muriate of lime	0·5
Common salt	3·0	Sulphate of potash	0·25
Silica	0·5	Carbonate of soda	0·25

River water.

River waters may be considered as merely a collection of spring and rain water, and therefore are usually

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* Bergman, i. 88.

† Nicholson's *Jour.* v. 237.

possessed of a degree of purity at least equal to these. Indeed, when their motion is rapid, and their bed siliceous sand, they are generally purer than spring water; 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 sulphate 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 carbonate. Mr Sennebier has shown 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 is seldom so transparent as river water, being usually contaminated with the remains of animal and vegetable bodies which have undergone putrefaction in it. For as lake water is often nearly stagnant, it does not oppose the putrefaction of these bodies, but rather promotes it; whereas in river water, which is constantly in motion, no putrefaction takes place. Hence the reason of the slimy appearance and the brownish colour which often distinguishes lake water.

Marsh water contains a still greater proportion of animal and vegetable remains than lake water, because it is altogether stagnant. Moss water is strongly impregnated with those vegetable bodies which constitute mosses, and usually also contains iron.

When water is kept in casks during sea voyages, it soon becomes putrid and offensive. This is owing to the action of the water upon the cask, a portion of which it dissolves. Berthollet suggested the charring of the inside of the cask as an effectual remedy. The experiment has been successfully tried in a long sea voyage of Krusenstern, a Russian captain. Charcoal powder acts effectually, but it is troublesome, and soon loses its property *.

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* *Ann. de Chim.* lix. 96, and Gehlen's *Jour.* 2d series, i. 645.

CHAP. II.

OF SEA WATER.

THE Ocean is the great reservoir of water into which the lakes and rivers empty themselves, and from which is again drawn by evaporation that moisture which, falling in showers of rain, fertilizes the earth, and supplies the waste of the springs and rivers. This constant circulation would naturally dispose one to believe, *a priori*, that the waters of the ocean do not differ much from the waters of rivers and lakes: but nothing would be more erroneous than such a conclusion; 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 32,058,939$\frac{1}{4}$ 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 substances with which it is mixed near the surface. Its specific gravity varies from 1·0269 to 1·0285 ‡. It does not freeze till cooled down to 28·5° § of Fahrenheit's scale.

Saline contents.

It has been ascertained by the experiments of different chemists ||, and especially by those of Bergman, that sea water holds in solution muriate of soda, muriate of magnesia, sulphate of magnesia, and sulphate of lime; besides the animal and vegetable bodies with which it is occasionally contaminated. The average quantity of saline ingredients is $\frac{1}{28}$. Bergman found water taken up from the depth of 60 fathoms, near the Canaries, by Dr Sparrman, to contain $\frac{1}{24}$. Lord Mulgrave found the water at the back of Yarmouth sands to contain about $\frac{1}{32}$ part. Bergman found water taken up from a depth of sixty fathoms to contain only the following salts in the following proportions.

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[*] *Mem. Par.* 1776, p. 213.

[†] Bergman, i. 180.

[‡] Bladh, Kirwan's *Geological Essays*, p. 355.

[§] Nairne, *Phil. Trans.* 1776, Part First.

[||] Monnet, Lavoisier, Baumé, &c. have published analyses of sea water.

Composition.

30·911	common salt
6·222	muriate of magnesia
1·000	sulphate of lime

Mr Lavoisier found 10,000 parts of sea water taken up on the west of Dieppe to contain the following salts:

1375	muriate of soda
256	muriate of lime and magnesia
156	muriate of magnesia
87	lime
64	sulphate of soda and magnesia
1958	

or almost $\frac{1}{5}$ of saline contents *; but this proportion is undoubtedly excessive. My analysis gives $\frac{1}{30}$ of saline contents in the water of the Frith of Forth. The salts which I found were the same as those announced by Bergman, sulphate of magnesia excepted, which exists in all the specimens of sea water that I have examined; and the proportion of it is considerable.

In different places.

As far as experiment has gone, the proportion of saline contents does not differ much, whatever be the latitude in which the water of the ocean is examined. Lord Mulgrave, in north latitude 80°, and 60 fathoms under ice, found the saline contents of sea water 0·0354; in latitude 74°, he found them 0·036; in latitude 60°, 0·034. Pages found sea water taken up in north latitude 45° and 39° to contain 0·04 of saline contents; and Baumé 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

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* *Mem. Par.* 1772, as quoted by Kirwan.

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.

Propor. of Salt.	Specific Gravity.	Propor. of Salt.	Specific Gravity.	Propor. of Salt	Specific Gravity.
0	1·000	1/21	1·032	1/84	1·007
1/2	1·206	1/24	1·029	1/108	1·006
1/4	1·160	1/27	1·027	1/126	1·005
1/5	1·121	1/28	1·025	1/144	1·004
1/6	1·107	1/30	1·024	1/162	1·003
1/7	1·096	1/32	1·023	1/192	1·0029
1/8	1·087	1/36	1·020	1/256	1·0023
1/9	1·074	1/39	1·019	1/320	1·0018
1/12	1·059	1/42	1·015	1/448	1·0017
1/14	1·050	1/48	1·014	1/512	1·0014
1/15	1·048	1/54	1·013	1/848	1·0008
1/16	1·045	1/56	1·012	1/1024	1·0006
1/18	1·040	1/72	1·009		

This Table was calculated at a temperature between 46° and 55°; but Mr Kirwan has reduced part of it to the temperature of 62°, in order to compare it with the 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:

Propor. of Salt.	Spec. Grav. at 62°.
1/24	1·0283
1/25	1·0275
1/26	1·0270
1/27	1·0267
1/28	1·0250
1/30	1·0233
1/39	1·0185
1/44	1·0133
1/56	1·0105
1/108	1·004
1/162	1·0023

Book II.

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 01	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 Teneriffe.

From this Table, compared with the last, we learn that the ocean contains most salt between south latitude 10° and 20°; the saline contents amounting to rather more than $\frac{1}{24}$th. The quantity of salt between north latitude 18° and 34° is rather less than $\frac{1}{24}$th: at the equator it is nearly $\frac{1}{25}$th. The proportion of salt is least of all in north latitude 57°, where it amounts to little more than $\frac{1}{27}$th.

Of the Baltic.

From the experiments of Wilcke, we learn that the Baltic contains much less salt than the ocean; that the proportion of its salt is increased by a west wind, and still more by a north-west wind. The specific gravity of the Baltic water, ascertained by this philosopher under these different circumstances, and reduced by Mr Kirwan to the temperature of 62°, is exhibited in the following 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 salt in the Baltic, when an east wind prevails, is only $\frac{1}{108}$; and that this proportion is doubled by a westerly storm: a proof not only that the saltness of the Baltic is derived from the neighbouring ocean, but that storms have a much greater effect upon the waters of the ocean than has been supposed *. The Euxine and Caspian Seas, if we believe Tournefort, are less salt

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* Kirwan's *Geological Essays*, p. 356.

than the ocean *; but it is probable that the Mediterranean is at least as salt as the Atlantic.

The Dead Sea.

The water of the *Dead Sea* differs exceedingly from sea water. Its specific gravity is 1·211 †; and it is saturated with salt, containing no less than 24·6 *per cent.* of saline matter. According to the analysis of Lavoisier, it is composed of

55·60	water
38·15	muriate of lime and of magnesia
6·25	common salt
100·00 ‡	

But by the late very accurate analysis of Dr Marcet, the constituents contained in 100 parts of the water of this lake, are in the following proportions:

3·920	muriate of lime
10·246	muriate of magnesia
10·360	muriate of soda
0·054	sulphate of lime
75·420	water
100·000 §	

The water of this lake, therefore, ought to be distinguished from sea water; and might with propriety be included among *mineral* waters. Dr Marcet found

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* Tournefort's *Voyages*, ii. 410.

† Marcet.

‡ *Mem. Par* 1778, p. 69.

§ Nicholson's *Jour.* xx. 25. The constituents of sulphate of lime, and of sulphate of barytes, being taken by Dr Marcet from the erroneous analyses of Chenevix, will make a small error in the quantity of sulphate of lime; but the quantity of this salt contained in the water is so small, that the error may be reckoned immaterial.

the constituents of the river Jordan, which flows into the Dead Sea, similar, but the salts do no exceed $\frac{1}{300}$th part of the solid contents.

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 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 17th 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 Bouldoc 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, Westrumb, 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.

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 $\frac{1}{28}$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 sulphureted 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 Limington 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 sulphureted 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 water generally containing from six to 40 cubic inches of this acid gas. According to Westrumb, 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. Sulphureted hydrogen gas constitutes the most conspicuous ingredient in those waters which are distinguished by the name of hepatic or sulphureous.

III. The only alkali which has been observed in mineral waters, uncombined, is soda; and the only earthy bodies are silica and lime.

3. Alkalies and earths.

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: *sulphates*, *nitrates*, *muriates*, *carbonates*, and *hydrosulphurets*:

1. Sulphate of soda
2. ....ammonia
3. ....lime
4. ....magnesia
5. ....alumina
6. ....iron
7. ....copper
8. Nitrate of potash
9. .... lime
10. Nitrate of magnesia
11. Muriate of potash
12. .... soda
13. .... ammonia
14. .... barytes
15. .... lime
16. .... magnesia
17. .... alumina
18. .... manganese

19. Carbonate of potash
20. ....soda
21. ....ammonia
22. ....lime
23. ....magnesia
24. Carbonate of alumina
25. ....iron
26. Hydrosulph. of lime
27. ....potash
28. And likewise borax

Of these genera the carbonates and muriates occur by far most commonly, and the nitrates most rarely.

1. Sulphate of soda is not uncommon, especially in those mineral waters which are distinguished by the epithet *saline*.

2. Sulphate of ammonia is found in mineral waters near volcanoes.

3. Sulphate of lime is exceedingly common in water. Its presence seems to have been first detected by Dr Lister in 1682.

4. Sulphate 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. Sulphate of iron occurs sometimes in volcanic mineral waters, and has even been observed in other places. But sulphate of copper is only found in the waters which issue from copper mines.

8. Nitre has been found in some springs in Hungary; but it is exceedingly uncommon.

9. Nitrate of lime was first detected in water by Dr Home of Edinburgh in 1756. It is said to occur in some springs in the sandy deserts of Arabia.

10. Nitrate of magnesia is said to have been found in some springs.

11. Muriate of potash is uncommon; but it has lately been discovered in the mineral springs of Uhleaborg in Sweden by Julin.

12. Muriate of soda is so exceedingly common in mineral waters, that hardly a single spring has been analysed without detecting some of it.

13. Muriate of ammonia is uncommon; but it has been found in some mineral springs in Italy and in Siberia.

14. Muriate of barytes is still more uncommon; but its presence in mineral waters has been announced by Bergman.

15. and 16. Muriates of lime and magnesia are common ingredients.

17. Muriate of alumina has been observed in waters by Dr Withering; but it is very uncommon.

18. Muriate of manganese was mentioned by Bergman as sometimes occurring in mineral waters. It has lately been detected by Lambe in the waters of Lemington Priors; but in an extremely limited proportion.

19. The presence of carbonate of potash in mineral waters has been mentioned by several chemists: if it does occur, it must be in a very small proportion.

20. But carbonate of soda is, perhaps, the most common ingredients of these liquids, if we except common salt and carbonate of lime.

21. Carbonate of ammonia has been discovered in waters; but it is uncommon.

22. Carbonate 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 ca-

pable of holding in solution 0·002 of carbonate 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 carbonate 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 carbonate of lime. When the proportion of water is increased, it is capable of holding the carbonate 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 carbonate 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 carbonate of lime in solution, provided the weight of the carbonic acid present exceed that of the lime *. These observations apply equally to the other earthy carbonates held in solution by mineral waters.

23. Carbonate of magnesia is also very common in mineral waters, and is almost always accompanied by carbonate of lime.

24. Carbonate of alumina is said to have been found

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* Kirwan on *Mineral Waters*, p. 15.

in waters; but its presence has not been properly ascertained.

25. But carbonate of iron is by no means uncommon; indeed it forms the most remarkable ingredient in those waters which are distinguished by the epithet of *chalybeate*.

26. and 27. The hydrosulphurets of lime and of soda have been frequently detected in those waters which are called sulphureous or hepatic.

28. Borax exists in some lakes in Persia and Thibet; but the nature of these waters has not been ascertained[*].

5. Vegetable and animal matters.

Besides these substances, certain vegetable and animal matters have been occasionally observed in mineral waters. But in most cases these are rather to be considered in the light of accidental mixtures than of real component parts of the waters in which they occur.

From the above enumeration, we are enabled to form a pretty accurate idea of the substances which occur in mineral waters; but this is by no means sufficient to make us acquainted with these liquids. No mineral water contains all of these substances. Seldom are there more than five or six of them present together, and hardly ever do they exceed the number of eight or 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 great-

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[*] Kirwan on *Mineral Waters*, p. 8, &c.

er 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 attention, 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 peculiar substance which predominates in each. Accordingly they have been divided into four classes; namely,

Mineral waters divided into four classes.

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 carbonates.

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. It 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 a sulphate; but this is uncommon. Waters containing

the sulphate of iron 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 carbonate of iron, and causes its base to precipitate.

3. Hepatic.

3. The hepatic or sulphureous waters are those which contain sulphureted hydrogen gas. These waters are easily distinguished by the odour of sulphureted 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 sulphureted 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 muriates or sulphates.

4. Saline.

4. Saline waters are those which contain only salts in 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 carbonate or the sulphate. 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 recognised by their salt taste, and like sea water usually contain some magnesian and calcareous salts. The waters of the third order contain sulphate of magnesia. They have a bitter taste and are purgative. Finally, the waters of the fourth order are alkaline, containing carbo-

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nate 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 particular description of each particular spring would be inconsistent with the plan of this Work*. But 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.

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[*] The reader will find an accurate account of the properties and constituents of the most celebrated mineral springs, both British and foreign, in Dr Saunders's *Treatise on the Chemical History and Medical powers of the most celebrated Mineral Waters.* From this excellent work I have borrowed several of the analyses which appear in the ensuing Table in the text.

		Gases. Cubic Inches.				Carbonates of				Muriates of				Sulphates of					
	Water.	Oxygen.	Carbonic acid.	Sulph. hydrog	Azotic.	Soda	Lime.	Mag.	Iron.	Soda.	Lime.	Mag.	Potash.	Soda.	Lime.	Mag.	Silica.	Alumina.	Resin.
Seltzer[1]	8949	·435	13·068	—	—	5·22	78·3	6·32	—	13·74	—	—	—	—	—	—	—	—	—
Spa[1]	8933	—	9·8	—		1·85	1·85	4·35	0·70	0·21	—	—	—	—	—	—	—	—	—
Pyrmont[1]	8950	--	19·6	—	—	—	4·3	9·8	0·70	1·7	—	—	—	—	8·38	5·44	—	—	—
Aix la Chapelle[1]	8940	—	—	13·06	—	15·25	5·98	—	—	6·21	—	—	—	—	—	—	—	—	—
Medvi[1]	8933	—	6·53	8·71	—	—	—	—	0·92	—	0·11	—	—	—	—	—	—	—	—
Carlsbad[2]	25320	—	50·	—	—	38·5	12·5	—	0·1¼	32·5	—	—	—	66·75	—	—	2·25	—	—
Leming. Priors[3]	5816	—	·5	—	3·5	—	—	—	·75	430·	—	11·5	—	15·2	112·	—	—	—	—
Pouges[4]	9216	—	16·7	—	—	10·4	12·4	1·2	—	2·2	—	—	—	—	—	—	3·2	0·35	—
Enghiem[5]	92160	—	18·5	70·	—	—	21·4	1·35	—	2·4	—	8·0	—	—	33·3	5·8	—	—	—
Lu[6]	36864	—	5·	2·	—	—	10·22	—	—	36·74	9·25	—	—	—	14·03	—	0·23	—	—
Geyzer[7]	10000	—	—	—	—	0·95*	—	—	—	2·46	—	—	—	1·46	—	—	5·4	0·48	—
Uhleaborg[8]	42250	—	0·	—	—	—	1·9	—	1·2	5·7	—	—	1	—	0·8	—	1·7	—	—
Teplisz[9]	22540	—	—	—	—	13·25	16·5	—	32·5	61·3	28·5	—	—	—	—	—	15·1	—	—
Kilburn[10]	138240	—	84·	36·	—	—	2·4	1·25	·3⅛	6·0	0·6	12·8	—	28·2	13·0	91·0	—	—	·6
Bristol[11]	103643	3·	30·	—	—	—	13·5	—	—	4·	—	7·25	—	11·25	11·75	—	—	—	—
Tunbridge[12]	103643	1·4	10·6	—	4·	—	—	—	1·	0·5	—	2·25	—	—	1·25	—	—	—	—
Cheltenham[13]	103643	—	30·368	—	15·	—	—	—	5·	5·	—	25·†	—	480·‡	40·	—	—	—	—
Harrowgate[14]	103643	—	8·	19·	7·	—	18·5	5·5	—	615·5	13·	91·	—	—	—	0·5	—	—	—
Moffat[14]	103643	—	1·	10·	4·	—	—	—	—	3·6	—	—	—	—	—	—	—	—	—
Bath[15]	15360	—	2·4	—	—	—	1·6	—	0·004	6·6	—	—	—	3·	18·	—	0·4	—	—

[1] Bergman. [2] Klaproth. [3] Lambe, *Man. Mem.* v. 174. [4] Hassenfratz, *Ann. de Chim.* i. 81. [5] Fourcroy, Ibid. vi. 172.

[6] Breze, Ibid. x. 44. [7] Black. [8] Julin, Crell's *Annals*, 1797, ii. 373. [9] Jahn, Ibid. i. 331. [10] Schmeisser, *Phil. Trans.* lxxxii. 127.

[11] Dr Carrick, Saunders on *Miner. Waters*, p. 118. [12] Dr Babington, Ibid. p. 241. [13] Fothergill, Ibid.

[14] Garnet, Ibid. p. 524 and 33. [15] Philips, *Phil. Mag.* xxiv. 342. * Pure Soda. † And sulphate of magnesia. ‡ And carbonate.

Chap. IV.

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 form the subject of the two following Sections.

SECT. I.

METHOD OF DETERMINING THE INGREDIENTS OF WATERS.

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 showed how they might be combined

Tests.

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 shown that paper stained with litmus is reddened when dipt into water containing $\frac{1}{3521}$ of sulphuric acid.

Sulphureted hydrogen,

IV. Water containing sulphureted hydrogen gas is distinguished by the following properties: 1. It exhales the peculiar odour of sulphureted hydrogen gas. 2. It

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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.

reddens the infusion of litmus fugaciously. 3. It blackens paper dipt into a solution of lead, and precipitates the nitrate of silver black or brown.

Alkaline and earthy carbonates,

V. Alkalies, and *alkaline* and *earthy carbonates*, are distinguished by the following tests: 1. The infusion of turmeric, or paper stained with turmeric, is rendered *brown* by alkalies, or reddish brown if the quantity be minute. This change is produced when the soda in water amounts only to $\frac{1}{2217}$ part*. 2. Paper stained with Brazil wood, or the infusion of Brazil wood, is rendered blue: but this change is produced also by the alkaline and earthy carbonates. Bergman ascertained that water containing $\frac{1}{9945}$ part of carbonate of soda renders paper stained with Brazil wood blue†. 3. Litmus paper reddened by vinegar is restored to its original blue colour. This change is produced by the alkaline and earthy carbonates also. 4. When these changes are fugacious, we may conclude that the alkali is ammonia.

Fixed alkalies,

IV. Fixed alkalies exist in water which occasions a precipitate with muriate of magnesia after being boiled. Volatile alkali may be distinguished by the smell, or it may be obtained in the receiver by distilling a portion of the water gently, and then it may be distinguished by the above tests.

Earthy and metallic carbonates,

VII. Earthy and metallic carbonates are precipitated

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* The same change is produced by lime water; but pure lime very seldom indeed occurs in mineral waters. It is needless to observe, that the alkalies produce the same effect on turmeric, whether they be pure or in the state of carbonates. The earthy carbonates have no effect on turmeric.

† Sulphate of lime likewise renders Brazil wood blue.

by boiling the water containing them; except carbonate 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 carbonate. The following observations of Westrumb on the colour which iron gives to nutgalls, as modified by other bodies, deserve attention.

A violet indicates an alkaline carbonate or earthy salt.

Dark purple indicates other alkaline salts.

Purplish red indicates sulphureted hydrogen gas *.

Whitish and then black indicates sulphate of lime.

Mr Philips has lately ascertained, that while the iron is in the state of protoxide, the presence of lime rather facilitates the application of this test; but the lime prevents the test from acting, provided the iron be in the state of peroxide †. 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. Muriate, nitrate, or acetate of barytes
2. ....strontian
3. ....lime
4. Nitrate or acetate of lead.

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* Or rather manganese, according to Kirwan.

† *Phil. Mag.* xxiv. 349.

Book II.

Of these the most powerful by far is muriate of barytes, which is capable of detecting the presence of sulphuric acid uncombined, when it does not exceed the millionth part of the water. Acetate of lead is next in point of power. The muriates are more powerful than the nitrates. The calcareous salts are least powerful. All these tests are capable of indicating a much smaller proportion of uncombined sulphuric acid than when it is combined with a base *. To render muriate of barytes a certain test of sulphuric acid, the following precautions must be observed: 1. The muriate must be diluted. 2. The alkalies, or alkaline carbonates, if the water contain any, must be previously saturated with muriatic acid. 3. The precipitate must be insoluble in muriatic acid. 4. If boracic acid be suspected, muriate of strontian must be tried, which is not precipitated by boracic acid. 5. The hydrosulphurets precipitate barytic solutions, but their presence is easily discovered by the smell.

Muriatic acid,

X. Muriatic acid is detected by nitrate of silver, which occasions a white precipitate or a cloud in water containing an exceedingly minute portion of this acid. To render this test certain, the following precautions are necessary: 1. The alkalies or carbonates must be previously saturated with nitric acid. 2. Sulphuric acid, if any be present, must be previously removed by means of nitrate of barytes. 3. The precipitate must be insoluble in nitric acid.

Boracic acid.

XI. Boracic acid is detected by means of acetate of lead, with which it forms a precipitate insoluble in ace-

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* Kirwan on *Mineral Waters*, p. 65.

tic acid. But to render this test certain, the alkalies and earths must be previously saturated with acetic acid, and the sulphuric and muriatic acids removed by means of acetate of strontian and acetate of silver.

Barytes,

XII. Barytes is detected by the insoluble white precipitate which it forms with diluted sulphuric acid.

Lime,

XIII. Lime is detected by means of oxalic acid, which 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 nitrate of barytes.

The alumina may be separated from the magnesia after both have been precipitated together, either by boiling the precipitate in pure potash, which dissolves the alumina and leaves the magnesia; or the precipitate may be dissolved in muriatic acid, precipitated by an alkaline carbonate, dried in the temperature of 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 general what the substances are which are found in the water we are examining; we must know also in what manner they are combined. Thus it is not sufficient to know that lime forms an ingredient in a particular water; we must know also the acid with which it is united. Mr Kirwan first pointed out how to accomplish this difficult task by means of tests. Let us take a short view of his method.

Sulphates.

I. To ascertain the presence of the different sulphates.

The sulphates which occur in water are seven; but one of these, namely, *sulphate of copper*, is so uncommon, that it may be excluded altogether. The same remark applies to sulphate of ammonia. It is almost unnecessary to observe, that no sulphate need be looked for unless both its acid and base have been previously detected in the water.

1. Alkaline,

1. Sulphate of soda may be detected by the following method: Free the water to be examined of all earthy sulphates by evaporating it to one-half, and adding lime-water as long as any precipitate appears. By this means the earths will all be precipitated except lime, and the only remaining earthy sulphate will be sulphate of lime, which will be separated by evaporating the liquid till it becomes concentrated, and then dropping into it a

little alcohol, and after filtration adding a little oxalic acid.

With the water thus purified, mix solution of lime. If a precipitate appears either immediately or on the addition of a little alcohol, it is a proof that sulphate of potash or of soda is present. Which of the two may be determined by mixing some of the purified water with acetate of barytes: Sulphate of barytes precipitates. Filter and evaporate to dryness. Digest the residuum in alcohol. It will dissolve the alkaline acetate. Evaporate to dryness, and the dry salt will deliquesce if it be acetate of potash, but effloresce if it be acetate of soda.

2. Calcareous,

2. Sulphate of lime may be detected by evaporating the water suspected to contain it to a few ounces. A precipitate appears, which, if it be sulphate of lime, is soluble in 500 parts of water; and the solution affords a precipitate with the muriate of barytes, oxalic acid, carbonate of magnesia, and with alcohol.

3. Alum,

3. Alum may be detected by mixing carbonate of lime with the water suspected to contain it. If a precipitate appears, it indicates the presence of alum, or at least of sulphate of alumina; provided the water contains no muriate of barytes or metallic sulphates. The first of these salts is incompatible with alum. The second may be removed by the alkaline prussiates. When a precipitate is produced in water by muriate of lime, carbonate of lime, and muriate of magnesia, we may conclude that it contains alum or sulphate of alumina.

4. Magnesian,

4. Sulphate 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 carbonet of lime, and provided

Book II. also that it contains no uncombined acid, nor even carbonic acid.

5. Of iron, 5. Sulphate of iron is precipitated from water by alcohol, and then it may be easily recognised by its properties.

Muriates. II. To ascertain the presence of the different muriates.

The muriates found in waters amount to eight, or to nine if muriate of iron be included. The most common by far is muriate of soda.

1. Alkaline, 1. Muriate of soda and of potash may be detected by the following method: Separate the sulphuric acid by alcohol and nitrate of barytes. Decompose the earthy nitrates and muriates by adding sulphuric acid. Expel the excess of muriatic and nitric acids by heat. Separate the sulphates thus formed by alcohol and barytes water. The water thus purified can contain nothing but alkaline nitrates and muriates. If it forms a precipitate with acetate of silver, we may conclude that it contains muriate of soda or of potash. To ascertain which, evaporate the liquid thus precipitated to dryness; dissolve the acetate in alcohol. Evaporate to dryness. The salt will deliquesce if it be acetate of potash, but effloresce if it be acetate of soda.

2. Barytic, 2. Muriate of barytes may be detected by sulphuric acid, as it is the only barytic salt hitherto found in waters.

3. Calcareous, 3. Muriate of lime may be detected by the following method: Free the water of sulphate of lime and other sulphates, by evaporating it to a few ounces, mixing it with spirit of wine, and adding last of all nitrate of barytes, as long as any precipitate appears. Filter off the water, evaporate to dryness, treat the dry mass

with alcohol, evaporate the alcohol to dryness, and dissolve the residuum in water. If this solution gives a precipitate with acetate of silver and oxalic acid, it *may* contain muriate of lime. It must contain it in that case, if, after being treated with carbonate of lime, it gives no precipitate with ammonia. If it does, separate the lime by means of oxalic acid, filter and distil with a gentle heat. If the liquid in the receiver gives a precipitate with nitrate of silver, muriate of lime existed in the water.

4. Magnesian,

4. Muriate of magnesia may be detected by separating all the sulphuric acid by means of nitrate 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 muriate 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 carbonate 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 muriate 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 nitrate of silver, the water contains muriate of magnesia.

5. Aluminous.

5. Muriate 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 nitrate of barytes. If the liquid thus purified gives a precipitate with carbonate of lime, it contains muriate of alumina. The muriate 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.

Nitrates.

III. To ascertain the presence of the different nitrates. The nitrates but seldom occur in waters; when they do, they may be detected by the following rules:

1. Alkaline,

1. Alkaline nitrates may be detected by freeing the water examined from sulphuric acid by means of acetate of barytes, and from muriatic acid by acetate of silver. Evaporate the filtered liquid, and treat the dry mass with alcohol; what the alcohol leaves can consist only of the alkaline nitrates and acetate of lime. Dissolve it in water. If carbonate of magnesia occasions a precipitate, lime is present. Separate the lime by means of carbonate of magnesia. Filter and evaporate to dryness, and treat the dried mass with alcohol. The alcohol now leaves only the alkaline nitrates, which may be easily recognised, and distinguished by their respective properties.

2. Calcareous,

2. Nitrate of lime. To detect this salt, concentrate the water, and mix it with alcohol to separate the sulphates. Filter and distil off the alcohol; then separate the muriatic acid by acetate 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 nitrate of lime.

3. Magnesian.

3. To detect nitrate of magnesia, the water is to be freed from sulphates and muriates 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 potash 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 nitrate 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 sulphates.............	Nitrates of lime and magnesia, Muriates of lime and magnesia.
2. Sulphate of lime	Alkalies, Carbonate of magnesia, Muriate of barytes.
3. Alum.................	Alkalies, Muriate of barytes, Nitrate, muriate, carbonate of lime, Carbonate of magnesia.

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* See Kirwan on *Mineral waters*, passim.

4. Sulphate of magnesia	Alkalies, Muriate of barytes, Nitrate and muriate of lime.
5. Sulphate of iron	Alkalies, Muriate of barytes, Earthy carbonates.
6. Muriate of barytes	Sulphates, Alkaline carbonates, Earthy carbonates.
7. Muriate of lime	Sulphates, except of lime, Alkaline carbonates, Carbonate of magnesia.
8. Muriate of magnesia	Alkaline carbonates, Alkaline sulphates.
9. Nitrate of lime	Alkaline carbonates, Carb. of magn. and alumina, Sulphates, except of lime.

Besides the substances above described, there is sometimes found in water a quantity of bitumen combined with alkali, and in the state of soap. In such waters acids occasion a coagulation; and the coagulum collected on a filter discovers its bituminous nature by its combustibility.

Water also sometimes contains *extractive matter*; the presence of which may be detected by means of nitrate of silver. The water suspected to contain it must be freed from sulphuric and nitric acid by means of nitrate of lead. After this, if it gives a brown precipitate with nitrate of silver, we may conclude that extractive matter is present *.

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* Westrumb.

SECT. II.

METHOD OF DETERMINING THE PROPORTION OF THE INGREDIENTS.

Formula for finding the saline contents of water.

THE proportion of saline ingredients, held in solution by any water, may be in some measure estimated from its specific gravity. The lighter a water is, the less saline matter does it contain; and, on the other hand, the 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 $\overline{1079 - 1000} \times 1{\cdot}4 = 110{\cdot}6 =$ 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

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* Kirwan on *Mineral Waters*, p. 145.

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.

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.

To estimate the gaseous bodies.

I. The different aerial fluids ought to be first separated and estimated. For this purpose a retort ought to be filled two-thirds with the water, and connected with a jar full of mercury, standing over a mercurial trough. Let the water be made to boil for a quarter of an hour. The aerial fluids will pass over into the jar. When the apparatus is cool, the quantity of air expelled from the water may be determined either by bringing the mercury within and without the jar to a level; or if that cannot be done, by reducing the air to the proper density by the formulas given in the first Chapter of the last Book. The air of the retort ought to be carefully subtracted, and the jar must be divided into cubic inches and tenths.

The only gaseous bodies contained in water are common air, oxygen gas, azotic gas, carbonic acid, sulphureted hydrogen gas, and sulphurous acid. The last two never exist in water together. The presence of either of them must be ascertained previously by the application of the proper tests. If sulphureted hydrogen gas be present, it will be mixed with the air contained in the glass jar, and must be separated before that air be examined. For this purpose, the jar must be carried into a tub of warm water, and nitric acid introduced, which will absorb the sulphureted hydrogen. The residuum is then to be again put into a mercurial jar and examined.

If the water contain sulphurous acid, this previous step is not necessary. Introduce into the air a solution of pure potash, and agitate the whole gently. The carbonic acid and sulphurous acid gas will be absorbed, and leave the other gases. Estimate the bulk of this residuum ; this, subtracted from the bulk of the whole, will give the bulk of the carbonic acid and sulphurous acids absorbed.

Evaporate the potash slowly nearly to dryness, and leave it exposed to the atmosphere. Sulphate of potash will be formed, which may be separated by dissolving the carbonate of potash by means of diluted muriatic acid and filtering the solution. 100 Grains of sulphate of potash 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 potash, 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 sulphureted 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 sulphureted 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.

To estimate the earthy carbonates.

II. After having estimated the gaseous bodies, the next step is to ascertain the proportions of the earthy carbonates. For this purpose it is necessary to deprive the water of its sulphureted hydrogen, if it contains any. This may be done, either by exposing it to the air for a considerable time, or by treating it with litharge. A sufficient quantity of the water thus purified (if necessary) is to be boiled for a quarter of an hour, and filtered when cool. The earthy carbonates remain on the filter.

The precipitate thus obtained may be carbonate of lime, of magnesia, of iron, of alumina; or even sulphate of lime. Let us suppose all of these substances to be present together. Treat the mixture with diluted muriatic acid, which will dissolve the whole except the alumina and sulphate of lime. Dry this residuum in a red heat, and note the weight. Then boil it in carbonate of soda; saturate the soda with muriatic acid, and boil the mixture for half an hour. Carbonate of lime and alumina precipitate. Dry this precipitate, and treat it with acetic acid. The lime will be dissolved, and the alumina will remain. Dry it and weigh it. Its weight subtracted from the original weight gives the proportion of sulphate of lime.

The muriatic solution contains lime, magnesia, and iron. Add ammonia as long as a reddish precipitate appears. The iron and part of the magnesia are thus separated. Dry the precipitate, and expose it to the air for some time in a heat of 200° ; than treat it with acetic acid to dissolve the magnesia, which solution is to be added to the muriatic solution. The iron is to be redissolved in muriatic acid, precipitated by an alkaline carbonate, dried, and weighed.

Add sulphuric acid to the muriatic solution as long as any precipitate appears ; then heat the solution and concentrate. Heat the sulphate of lime thus obtained to redness, and weigh it. 100 Grains of it are equivalent to 70 of carbonate of lime dried. Precipitate the magnesia by means of carbonate 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 muriate of soda and the sulphate of lime, if any be still present. What remains behind is carbonate of magnesia. Weigh it, and add its weight to the former. The sulphate 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 barytes water, and ignite the precipitate. 100 Grains of sulphate of barytes thus formed indicate 23·5 of real sulphuric acid.

2. Saturate the muriatic acid with barytes water, and then precipitate the barytes by sulphuric acid. One hundred parts of the ignited precipitate are equivalent to 21 grains of real muriatic acid.

3. Precipitate the boracic acid by means of acetate of lead. Decompose the borate 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 carbonates.

4. To estimate the proportion of alkaline carbonate 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 potash, and 78·32 soda.

To estimate sulphates.

IV. Let us now consider the method of ascertaining the proportion of the different sulphates. These are six in number; the alkaline sulphates, and those of lime, alumina, magnesia, and iron.

1. Alkaline,

1. The alkaline sulphates may be estimated by precipitating their acid by means of nitrate of barytes, having previously freed the water of all other sulphates: for 170 grains of ignited sulphate of barytes indicate 100 grains of dried sulphate of soda; while 136·36 grains of sulphate of barytes indicate 100 of dry sulphate of potash.

2. Calcareous,

2. Sulphate of lime is easily estimated by evaporating the liquid containing it to a few ounces (having previously saturated the earthy carbonates with nitric acid), and precipitating the sulphate 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 carbonate 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. Sulphate of magnesia may be estimated, provided no other sulphate be present, by precipitating the acid by means of a barytic salt, as 100 parts of ignited sulphate of barytes indicate 52·11 of sulphate of magnesia. If sulphate of lime, and no other sulphate accompany it, this last may be decomposed, and the lime precipitated by carbonate of magnesia. The weight of the lime thus obtained enables us to ascertain the quantity of sulphate 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 sulphate of lime, there remains that which was combined with the magnesia, from which the sulphate of magnesia may be easily estimated.

If sulphate of soda be present, no earthy nitrate or muriate can exist. Therefore, if no other earthy sulphate be present, the magnesia may be precipitated by soda, dried, and weighed; 36·68 grains of which indicate 100 grains of dried sulphate of magnesia. The same process succeeds when sulphate of lime accompanies these two sulphates; 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 sulphate of magnesia, and leaves the other salt. Let the sulphate of magnesia be evaporated to dryness, exposed to a heat of 400°, and weighed. The same process succeeds if alum be present instead of sulphate of lime.

The precipitate in that case, previously dried, is to be treated with acetic acid, which dissolves the magnesia and leaves the alumina. The magnesia may be again precipitated, dried, and weighed. If sulphate 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 sulphate of alumina, thus formed, precipitate in the state of an insoluble powder. The sulphate of magnesia may then be estimated by the rules above explained.

5. Of iron.

5. Sulphate 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 prussiate in a solution of a given weight of sulphate of iron in water. If muriate of iron be also present, which is a very rare case, it may be separated by evaporating the water to dryness, treating the residuum with alcohol, which dissolves the muriate, and leaves the sulphate. Or the sulphate may be estimated with great precision by the rules laid down by Mr Kirwan *.

Estimation of muriates.

V. Let us now consider the method of estimating the quantity of the different muriates which may exist in waters.

1. Alkaline,

If muriate of potash or of soda, without any other salt, exist in water, we have only to decompose them by nitrate of silver, and dry the precipitate; for 217·65 of muriate of silver indicate 100 of muriate of potash, and 235 of muriate of silver indicate 100 of common salt.

The same process is to be followed if the alkaline carbonates be present; only these carbonates must be

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* *On Mineral Waters*, p. 220.

previously saturated with sulphuric acid; and we must precipitate the muriatic acid by means of sulphate of silver instead of nitrate. The presence of sulphate of soda does not injure the success of this process.

If muriate of ammonia accompany either of the fixed alkaline sulphates without the presence of any other salt, decompose the sal ammoniac by barytes water, expel the ammonia by boiling, precipitate the barytes by diluted sulphuric acid, saturate the muriatic acid with soda. The sulphate of barytes thus precipitated indicates the quantity of muriate of ammonia; 100 grains of sulphur indicating 49·09 grains of that salt. If sulphates be present in the solution, they ought to be previously separated.

2. Earthy

If common salt be accompanied by muriate of lime, muriate of magnesia, muriate of alumina, or muriate of iron, or by all of these together, without any other salts, the earths may be precipitated by barytes 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 muriate contained in the water. For 50 grains of lime indicate 100 of dried muriate of lime; 30 grains of magnesia indicate 100 of the muriate of that earth; and 21·8 grains of alumina indicate 100 of the muriate 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 sulphates and muriates exist together, they ought to be separated, either by precipitating the sulphates by means of alcohol, or by evaporating the whole to dryness, and dissolving the earthy muriates in alcohol. The salts thus separated may be estimated by the rules already laid down.

When alkaline and earthy muriates and sulphate of lime occur together, this last salt is to be decomposed by means of muriate of barytes. The precipitate ascertains the weight of sulphate of lime contained in the water. The estimation is then to be conducted as when nothing but muriates are present; only from the muriate of lime that proportion of muriate must be deducted which is known to have been formed by the infusion of the muriate of barytes.

When muriates of soda, magnesia, and alumina, are present together with sulphates of lime and magnesia, the water to be examined ought to be divided into two equal portions. To the one portion add carbonate of magnesia till the whole of the lime and alumina be precipitated. Ascertain the quantity of lime, which gives the proportion of sulphate of lime. Precipitate the sulphuric acid by muriate of barytes. This gives the quantity contained in the sulphate of magnesia and sulphate of lime; subtracting this last portion, we have the quantity of sulphate 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 muriate of magnesia and of alumina contained in the water, subtracting that part of the magnesia which existed in the state of sulphate, as indicated by the examination of the first portion of water. After this estimation precipitate the sulphuric acid by barytes water, and the lime by carbonic acid. The liquid evaporated to dryness leaves the common salt.

Estimation of nitrates,

VI. It now only remains to explain the method of ascertaining the proportion of the nitrates which may exist in waters.

1. Alkaline,

1. When nitre accompanies sulphates and muriates without any other nitrate, the sulphates are to be decomposed by acetate of barytes, and the muriates by acetate of silver. The water, after filtration, is to be evaporated to dryness, and the residuum treated with alcohol, which dissolves the acetates 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.

2. Earthy,

2. If nitre, common salt, nitrate of lime, and muriate 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 muriate of magnesia, nitrate of lime, and muriate of lime. Precipitate the muriatic acid by nitrate of silver, which gives the proportion of muriate of magnesia and of lime. Separate the magnesia by means of carbonate of lime, and note its quantity. This gives us the quantity of muriate 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 muriate 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 sulphate thus formed that portion formed by the carbonate of lime added, and by the lime contained in the muriate, the residuum gives us the lime contained in the original nitrate; and 35 grains of lime form 100 of dry nitrate of lime.

BOOK III.

OF

MINERALS.

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 every where forming, and travels of discovery are succeeding each other without in-

Book III.

termission. The fruit of these labours has been the discovery of no less than five new earths and eight new metals; besides a vast number of useful minerals which had been formely unknown or disregarded.

Mineralogy, as far as it is a chemical science, includes under it three different topics; namely, 1. An account of the properties and constituents of minerals. 2. An account of the various combinations which these bodies form; or of *compound minerals*, as they have been called. 3. The art of analysing minerals. These three topics will occupy our attention in their order. But as a technical language has been adopted by mineralogists in their descriptions, it will be necessary, in the first place, in order to render this Book intelligible, to premise a few observations on that subject.

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 convey 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*.

The object of this celebrated philosopher was to invent a method of describing minerals with such precision, that every species could readily be recognised by those who were acquainted with the terms employed. For this purpose, it was necessary to make use of those properties only which presented themselves to our senses on inspecting the mineral. These accordingly were chosen, and called by Werner *external characters*; because they may be ascertained without destroying the mineral examined. The following is a short sketch of the language invented by Werner, and employed by him in the description of minerals *.

He divides the characters of minerals into two kinds, namely, *general* and *particular*.

The general characters are the following: 1. Colour; 2. Cohesion; 3. Unctuosity; 4. Coldness; 5. Weight; 6. Smell; 7. Taste.

The particular characters are the following: 1. Aspect of the surface; 1. Aspect of the fracture; 3. Aspect of the distinct concretions; 4. General aspect; 5. Hardness; 6. Tenacity; 7. Frangibility; 8. Flexibility; 9. Adhesion to the tongue; 10. the sound.

I. General Characters.

Colour.

I. Colour. The colours of minerals are extremely various. Werner conceives eight fundamental colours,

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* For a more complete view of this important subject, the reader is referred to Professor Jameson's treatise on the *External Characters of Minerals*.

and describes all the others as compounds of various proportions of these. The fundamental colours are,

1. Snow white. The colour of new fallen snow.

2. Ash grey. The colour of well burnt wood ashes.

3. Velvet black. The colour of black velvet.

4. Berlin blue. The colour of prussian blue.

5. Emerald green. The colour of the emerald.

6. Lemon yellow. The colour of ripe lemons.

7. Carmine red.

8. Chesnut brown. The colour of the ripe chesnut.

The following Table exhibits the principle subordinate colours, placed in the order in which they pass into each other:

1. *Whites.*

Snow white.

Reddish white. Snow white with a little crimson red and ash grey.

Yellowish white. Snow white with a little lemon yellow and ash grey.

Silver white. Yellowish white with a metallic lustre.

Greyish white. Snow white with a little ash grey.

Greenish white. Snow white with a little emerald green and ash grey.

Milk white. Snow white with a little Berlin blue and ash grey.

Tin white. Milk white of a metallic lustre.

2. *Greys.*

Lead grey. Ash grey with a little blue and the metallic lustre.

Bluish grey. Ash grey with a little blue.

Smoke grey. Ash grey with a little brown.

Pearl grey. Ash grey with a little crimson red and blue.

Greenish grey. Ash grey with a little emerald green, and sometimes a trace of yellow.

Yellowish grey. Ash grey with lemon yellow and a trace of brown.

Ash grey.

Steel grey. Ash grey with a little blue and a metallic lustre.

3. *Blacks.*

Greyish black. Velvet black with a little ash grey.

Iron black. Darker than the preceding with a metallic lustre.

Velvet black.

Pitch black. Velvet black with a little brown and yellow.

Raven black. Velvet black with a little brown, yellow, and green.

Bluish black. Velvet black with a little blue.

4. *Blues.*

Indigo blue. Berlin blue with grey and a little black.

Berlin blue.

Azure blue. Berlin blue with a little red.

Violet blue. Berlin blue with much red and a little brown.

Plum blue. The preceding with more red and a very little black.

Lavender blue. Violet blue with a little grey.

Smalt blue. Berlin blue with white, a little grey, and a trace of red.

Sky blue. Berlin blue, white, and a little emerald green.

5. *Greens.*

Verdigris green. Emerald green with much Berlin blue and a little white.

Sea green. The preceding with a mixture of ash grey.

Mountain green. Verdigris green with a little yellowish grey.

Emerald green.

Apple green. Emerald green with a little greyish white.

Grass green. Emerald green with a little lemon yellow.

Blackish green. Green mixed with a considerable portion of black.

Pistachio green. Emerald green with a little yellow and some brown.

Asparagus green. Pistachio green with a little greyish white.

Olive green. Grass green with much brown.

Oil green. Pistachio green with much yellow and ash grey.

Siskin green. Emerald green with much lemon yellow and a little white.

6. *Yellows.*

Sulphur yellow. Lemon yellow with much emerald green and white.

Brass yellow. The preceding with the metallic lustre and a little grey.

Straw yellow. Sulphur yellow with much greyish white.

Bronze yellow. Brass yellow with a little steel grey and a trace of reddish brown.

Wax yellow. Lemon yellow, reddish brown, and a little ash grey.

Honey yellow. Sulphur yellow with chesnut brown.

Lemon yellow.

Gold yellow. Lemon yellow with the metallic lustre.

Ochre yellow. Lemon yellow with a considerable quantity of chesnut brown.

Wine yellow. Lemon yellow with reddish brown and grey.

Cream or Isabella yellow. Lemon yellow with greyish white and a little brown and red.

Orange yellow. Lemon yellow with a little carmine red.

7. *Reds.*

Aurora red. Carmine red with much lemon yellow.

Hyacinth red. Carmine red with lemon yellow and a little brown.

Tile red. The preceding mixed with much greyish white.

Scarlet red. Carmine red with a very little lemon yellow.

Blood red. Scarlet red mixed with brownish black.

Flesh red. Blood red mixed with greyish white.

Copper red. The preceding, nearly with the metallic lustre.

Carmine red.

Cochineal red. Carmine red mixed with bluish grey.

Crimson red. Carmine red with a considerable portion of blue.

Columbine red. The preceding with more blue and a little black.

Rose red. Cochineal red mixed with white.

Peach blossom red. Crimson red mixed with white.

Cherry red. Crimson red mixed with a considerable portion of brownish black.

Brownish red. Blood red mixed with brown.

8. *Browns.*

Reddish brown. Chesnut brown with a little red and yellow.

Clove brown. Chesnut brown with a cochineal red and a little black.

Hair brown. Clove brown with ash grey.

Broccoli brown. Clove brown with ash grey and blue.

Chesnut brown.

Yellowish brown. Chesnut brown with a considerable portion of lemon yellow.

Pinchbeck brown. The preceding with the metallic lustre.

Wood brown. Yellowish brown with much ash grey.

Liver brown. Chesnut brown with olive green and ash grey.

Blackish brown. Chesnut brown and black.

In respect of *intensity*, colours are either *dark*, *deep*, *light*, or *pale*. When a colour cannot be referred to any of the preceding, but is a mixture of two, this is expressed by saying, that the prevailing one *inclines* towards the other, if it has only a small tint of it; *passes* into it, if it has a greater.

When the colour of the surface of a mineral differs from its internal colour, the origin of this difference is pointed out, and the kind of colour is described. Notice is taken also whether the surface reflects the prismatic spectrum, or reflects different brilliant colours, like the *opal*, when its position is altered.

When the original colour of a mineral is changed altogether, and it has assumed another, it is then said to be tarnished.

When different colours appear in the same mineral, they may be disposed in *clouds*, *dots*, *streaks*, *rings*, *veins*, *zones*, &c.

Cohesion.

II. COHESION. With respect to cohesion, minerals are either *solid*, *friable*, or *fluid*.

Unctuosity.

III. The UNCTUOSITY. Minerals are distinguished into *greasy* and *meagre*. The first have a certain degree of greasiness in the feel; the second not.

IV. Coldness. V. Specific gravity. VI. Smell. VII. Taste.	These characters require no particular description.

II. PARTICULAR CHARACTERS.

Surface.

I. ASPECT OF THE SURFACE. In considering the external aspect or surface of a mineral, three things claim our attention; namely, 1. The *shape* of the mineral; 2. The kind of *surface*; 3. The *lustre* of the surface.

1. *External shape.*

The external shape is of four kinds: 1. Common; 2. Particular; 3. Regular; 4. Extraneous.

(1.) *Common*. The form is said to be *common* when it is too irregular to be compared to the form of any other body.

When a mineral constitutes a part of a solid rock or compound stone, it is called *massive*, when its bulk is not less than a hazel nut; when smaller than this, it is said to be *disseminated*. When it occurs loose, it is either in *angular pieces*, in *grains*, in *plates*, or in *membranes*.

(2.) Particular. The shape of a mineral is said to be particular when it can be referred to that of some known body. Such shapes are divided into five kinds; namely, *long*, *round*, *flat*, *cavernous*, and *entangled*.

The *long* are divided into the following: *Dentiform*, *filiform*, *capillary*, *reticulated*, *dendritic*, *coralloidal*, *stalactitic*, *cylindrical*, *tubiform*, *claviform*, *fruticose*. The *round* are the following: *Globular*, *botryoidal*, *reniform*, *tuberose*, *fusiform*. The *flat* are *specular*, in *leaves*. The *cavernous* are *cellular*, *perforated*, *corroded*, *amorphous*, *vesicular*. The *entangled* is *ramose*. The words in these cases indicate the particular shape which the mineral resembles *.

(3.) Regular. The form of minerals is said to be regular when they occur crystallized.

(4.) Extraneous. Under this head are included all the petrifactions.

2. *External surface.*

The surface of minerals is, 1. *Uneven*, having small unequal elevations and depressions; *granulated*, composed of small round elevations, like *shagreen*; *rough*, when the elevations felt are too small to be distinctly seen; *smooth*; *streaked*; *drusy*, coated with small crystals.

3. *External lustre.*

The lustre, in point of *intensity*, is of five kinds: 1. *Splendent*, when in full day light the lustre can be seen

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* For a more minute account the reader is referred to Professor Jameson's treatise on the *External Characters of Minerals*.

at a great distance; 2. *Shining*, when at a distance the light reflected is weak; 3. *Glistening*, when the lustre is only observable when the mineral is at no greater distance than an arm's length; 4. *Glimmering*, when the surface held near the eye in full day light presents a number of shining points; 5. *Dull*, when the surface has no lustre.

Lustre is of two kinds, the *metallic* and the *common*; the latter is subdivided into *semimetallic*, *adamantine*, *pearly*, *resinous*, *glassy*.

Fracture.

II. ASPECT OF THE FRACTURE. When a mineral is broken, the new surface exposed is called the *fracture*. Three things claim attention: 1. The *lustre* of the fracture; 2. The *kind* of fracture; 3. The *shape* of the fragments.

1. *Lustre of the fracture.*

This is called the *internal* lustre, and is distinguished in the same way as the external lustre.

2. *The kind of fracture.*

By this is meant the appearance which the internal surface of a mineral presents when broken, provided it be not fractured in the direction of one of the natural points of the mineral. This appearance obviously depends upon the texture of the mineral. The fracture is either, 1. Compact; 2. Fibrous; 3. Radiated; or, 4. Foliated.

(1.) *Compact*. The fracture is called compact when all the parts of the internal surface are continuous. The small inequalities which occur in this fracture are thus distinguished: 1. *Splintery*, when on a surface nearly even small wedgeshaped or scaly parts are seen adhering by their thicker end, and allowing a little light to pass. 2. *Even,* destitute of perceptible inequalities. 3. *Conchoidal,* small roundish elevations and depressions like the print of shells. 4. *Uneven,* having many small, sharp, abrupt, irregular elevations and inequalities; and from the size of these, this fracture is denominated *coarse, small,* or *fine.* 5. *Earthy,* when the internal surface resembles dried earth. 6. *Hackly,* having many very minute sharp hooks, more sensible to the hand than the eye. This last fracture is peculiar to the metals.

(2.) *Fibrous.* The fracture is called fibrous when the internal surface shows the mineral composed of fibres or threads adhering together, and too small to be measured. These fibres are either *straight* or *curved,* and they are disposed either in *parallels,* or they *diverge* from each other, or they are *interwoven* together.

(3.) *Radiated.* The fracture is called radiated when the fibres are flattish and so large that their breadth admits of measurement. The internal surface in that case exhibits *striæ* or *channels.*

(4.) *Foliated.* The fracture is called *foliated* when the mineral appears composed of thin plates whose surfaces are smooth and polished like the surface of a crystal. The plates may be either *large, small,* or *very small; perfect* or *imperfect; straight,* or *curved* in various ways. The direction of the plates, or the *clivage,* may be either simple, double, triple, &c.

3. *The shape of the fragments.*

By this is meant the shape of the pieces into which a mineral breaks when struck with a hammer. They are either, 1. *Regular;* or, 2. *Irregular.*

(1.) By *regular* fragments are meant those which have a geometrical form. They are usually the fragments of crystallized bodies; and are either *cubic*, *rhomboidal*, *trapezoidal*, *tetrahedral*, *octahedral*, or *dodecahedral*.

(2.) By *irregular* are meant the fragments which have not a geometrical form. They are *wedge-shaped*; *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*.

Distinct concretions.

III. ASPECT OF THE DISTINCT CONCRETIONS. Distinct concretions are distinct masses, of which certain minerals are composed, which may be separated from each other without breaking through the solid part of the mineral. They are separated from each other by natural seams. Three particulars respecting these concretions are to be attended to: 1. Their *shape*; 2. Their *surface*; 3. Their *lustre*.

1. *Shape of the distinct concretions.*

There are three kinds of shapes: 1. The *granular*. When the length, breadth, and thickness of a distinct concretion are nearly equal, it is said to be granular. Such concretions may be either *round* or *angular*; *large*, *coarse*, *small*, *fine*. 2. The *lamellar*, when the concretions consist of plates laid upon each other, and adhering more or less strongly. 3. The *columnar*, when the breadth and thickness are inconsiderable compared to the length.

2. *Surface of the distinct concretions.*

The surface is *smooth*, *rough*, *streaked*, *uneven*, &c.

3. *The lustre of the distinct concretions.*

It is distinguished in the same way as the external lustre.

General aspect.

IV. GENERAL ASPECT. Under this head three particulars are comprehended; namely, 1. The *transparency*; 2. The *streak*; 3. The *soiling*.

1. *The transparency.*

By transparency is meant the proportion of light which minerals are capable of transmitting. They are *transparent* when objects can be seen distinctly through them; *semitransparent*, when objects are seen through them indistinctly; *translucent*, when light passes, but in so small a quantity that objects cannot be seen through them *; *opaque*, when no light is transmitted.

When opaque minerals become transparent in water, they are called *hydrophanous*. When objects are seen double through a transparent mineral, it is said to *refract doubly*.

2. *The streak or scratch,*

Is the mark left when a mineral is scratched by any hard body, as the point of a knife. It is either *similar*, of the same colour with the mineral; or *dissimilar*, of a different colour.

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* According to Mr Kirwan's method, I have denoted these three degrees of transparency by the figures 4, 3, 2. When a mineral is translucent only at the edge, that is denoted by the figure 1. Opacity is sometimes denoted by 0.

3. *The soiling,*

Is the trace which some minerals leave when rubbed on the fingers or on paper. Some minerals leave a *stain* or trace, others not. Some of the first kind may be employed to write with, others not.

Hardness.

V. HARDNESS. By this is meant the resistance which a body opposes when we attempt to scratch it. Minerals are either, 1. Hard; 2. Semihard; 3. Soft.

(1.) Minerals are called *hard* when they do not yield to the knife, and strike fire with steel. There are three degrees of it: 1. Extremely hard, not yielding to the file; 2. Very hard, yielding a little to the file: 3. Hard, yielding to the file.

(2.) Minerals are *semihard* when they yield with difficulty to the knife, and do not strike fire with steel.

(3.) *Soft,* when they yield easily to the knife, but not to the nail.

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. 148. of this Work.

Tenacity.

VI. TENACITY. With respect to tenacity, minerals are, 1. *Brittle,* when on being cut with a knife the particles fly away with noise; 2. *Sectile,* when on being cut with a knife the particles do not fly off, but remain; 3. *Ductile,* when the mineral can be cut into slices.

Frangibility.

VII. FRANGIBILITY. By this is meant the resistance which minerals make when we attempt to break them. The degrees are five; namely, 1. *Very tough;*

2. *Tough*; 3. *Moderately tough*; 4. *Fragile*; 5. *Very fragile*.

Flexibility.

VIII. FLEXIBILITY. By this is meant the property of bending without breaking. Some minerals are, (1.) *Flexible*; and of these some are, 1. Elastic; others, 2. Common. (2.) Others *inflexible*.

Adherence.

IX. ADHERENCE TO THE TONGUE. Some minerals adhere, 1. Very *strongly*; 2. Others *moderately*; 3. Others *slightly*; 4. And others very *slightly*.

Sound.

X. By SOUND, is meant the peculiar noise emitted by some minerals when struck or bent. Some give a *ringing* sound; others a *grating* sound; others a *creaking* sound, as tin.

The particular properties of friable and fluid minerals require no description.

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*.

Blowpipe.

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 blowpipe 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 blowpipe by the lungs of the experimenter, or by means of bellows attached to the blowpipe. 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 temperature, as of borax, soda, microcosmic salt, &c. The properties which these experiments bring into view, enable us in many cases to ascertain the nature, and even the component parts of a mineral.

The blowpipe was first introduced into mineralogy by Von Swab. It was afterwards improved by Cronstedt, and still farther by Bergman. Saussure substituted a fine splinter of cyanite for charcoal, cemented a very minute portion of the mineral to be examined to the point of this splinter, and exposed it in that situation to the action of the blowpipe. By this contrivance he was enabled to make his experiments upon very minute particles; and this enabled him to fuse many bodies formerly considered as infusible.

CHAP. II.

OF SIMPLE 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 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 adopt-

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* 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 Lepidum*, chap. iii. *Theatrum Chemicum*, t. iv. p. 997.

ed in the present Work, because none which are preferable have been hitherto proposed.

Division.

I shall therefore divide minerals into four Classes:

1. Stones;
2. Salts;
3. Combustibles;
4. Ores.

The first Class comprehends all the minerals which are composed chiefly 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.
Order I.

CLASS I.

STONES.

THIS class naturally divides itself into two orders. The first order comprehends under it all the combinations composed entirely of earthy bodies, or of earthy bodies united with only a small portion of an alkali or metallic oxide: The second order consists of combinations of earthy bodies with acids. To the first order, for want of a better term, we shall give the appellation *earthy stones*; to the second, that of *saline stones*.

ORDER I. EARTHY STONES.

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, *calcareæ*, *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

Book III.
Chap. II.

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 latest Wernerian catalogues as follows:

1. Diamond genus
2. Zircon genus
3. Siliceous genus
3. Argillaceous genus
5. Magnesian genus
6. Calcareous genus
7. Barytic genus
8. Strontian genus
9. Hallite genus

Mr Kirwan and Professor Jameson, in their very valuable systems of mineralogy, have 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.

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, 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 no doubt that Werner is fully aware of this defect, and that he is gradually correcting it. His arrangement of this order of minerals, as it has been recently improved, is entitled almost to unlimited praise; but were he to omit the present genera altogether, and to substitute in their place those groups of minerals which he at present denominates *families*, I should consider it as far better than the mixture of two systems, one founded on the chemical, the other on the external characters, to which he still adheres. I am almost tempted to suspect that this is the plan which he has formed long ago, and that the apprehension of provoking the chemists to declare against him, has alone prevented him hitherto from putting it in execution. Such an apprehension, however, I am persuaded is altogether groundless. Every body must be sensible that *external characters* alone ought to influence us in the arrangement of minerals, and that those bodies ought to be placed nearest each other which possess the greatest resemblance. It is extremely probable, that whenever the external characters coincide, so also does the composition; and that when chemists obtain a contrary result, the reason probably is, that they have given the *same* name to minerals possessed of *different* characters. The knowledge of the external characters must come first, and can alone enable us to discriminate correctly the proper specimens which ought to be subjected to analysis; for I include under this title Hauy's important discoveries relative to the primitive form of crystallized minerals.

I shall therefore adopt the Wernerian arrangement of this order, discarding the old genera and substituting the families in their place. The following Table exhibits the different minerals of this order, arranged according to their families *.

Table of the species.

- I. *Diamond Family*
  - Diamond
- II. *Zircon Family*
  - Zircon
  - Hyacinth
  - Cinnamon-stone
- III. *Chrysolite Family*
  - Chrysoberyl
  - Chrysolite
  - Olivine
  - Coccolite
  - Augite
  - Diopside
  - Vesuvian
- IV. *Garnet Family*
  - Leucite
  - Melanite
  - Garnet
  - Granatite
  - Pyrope
- V. *Ruby Family*
  - Ceylanite
  - Spinell
  - Sapphire
  - Emery
  - Corundum
  - Adamantine spar
  - Automolite
- VI. *Topaz Family*
  - Topaz
  - Fibrolite
  - Sommite
- VII. *Schorl Family*
  - Euclase
  - Emerald
  - Beryl
  - Schorlite
  - Schorl
  - Pistazite
  - Zoisite
  - Axinite
- VIII. *Quartz Family*
  - Quartz
  - Iron-flint
  - Horn-stone
  - Flint-slate
  - Flint
  - Chalcedony
  - Hyalite

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* This Table, with a very few exceptions, is in the order of Werner's table, published at the end of Professor Jameson's Mineralogy.

Class I.
Order I.

- Opal
- Menilite
- Jasper
- Heliotrope
- Chrysoprase
- Plasma
- Cat's eye
- IX. *Pitch-stone Family*
  - Obsidian
  - Pitch-stone
  - Pearl-stone
  - Pumice
- X. *Zeolite Family*
  - Wavellite
  - Prehnite
  - Needle-stone
  - Zeolite
  - Analcime
  - Chabasie
  - Staurolite
  - Lomonite
  - Dipyre
  - Natrolite
  - Azurite
  - Lazulite
- XI. *Felspar Family*
  - Andaluzite
  - Felspar
  - Meionite
  - Scapolite
  - Wernerite
  - Spodumene
  - Ichthyophthalmite
- XII. *Clay Family*
  - Native alumina
  - Porcelain earth
  - Common clay
  - Clay-stone
  - Adhesive slate
  - Polishing slate
  - Tripoli
  - Float-stone
  - Alum-stone
- XIII. *Clay-slate Family*
  - Alum-slate
  - Bituminous shale
  - Drawing-slate
  - Whet-slate
  - Clay-slate
- XIV. *Mica Family*
  - Lepidolite
  - Mica
  - Pinite
  - Pot-stone
  - Chlorite
- XV. *Trap Family*
  - Diaspore
  - Hornblende
  - Smaragdite
  - Basalt
  - Wacke
  - Clink-stone
  - Iron-clay
- XIV. *Lithomarge Family*
  - Green earth
  - Lithomarge

Rocksoap
Umber
Yellow earth

XVII. *Soap-stone Family*

Native magnesia
Bole
Cimolite
Meerschaum
Fuller's earth
Steatite
Bildstein

XVIII. *Talc Family*

Nephrite
Serpentine
Schillerstone
Talc
Asbestus

XIX. *Actinolite Family*

Actinolite
Smasagdite
Tremolite
Antophyllite
Cyanite
Sahlite
Schalstone

XX. *Gadolinite Family*

Gadolinite

The minerals belonging to this order possess the following common properties: A specific gravity varying from 4·4 to 0·7. The greater number of them are hard enough to scratch glass; and this is always the case when the specific gravity exceeds 3·5. Some of them, however, are soft. None of them have the true metallic lustre; though some possess the false metallic lustre, which disappears on scratching them. None of them are soluble in water; and very few of them are soluble in acids without some particular mode of applying them. Hitherto it has been impossible for chemists to form any of them by art.

I. Diamond Family.

To this family there belongs only a single species; namely, the diamond, which is the hardest and the most beautiful of all the mineral productions.

Sp. 1. *Diamond.*

This mineral, which was well known to the ancients, is found in different parts of Asia, particularly in the kingdoms of Golconda and Visapour. It occurs also in Brazil, but has hitherto been confined to countries within the tropics.

Its most common colours are white and grey, of various shades. It occurs also blue, red, brown, yellow, and green. The colours are commonly pale. It is always crystallized; but sometimes so imperfectly, that at the first sight it might pass for amorphous. Its primitive form is a regular octahedron; but it more commonly assumes a spheroidal form, and then has usually 36 curvilinear triangular faces, six of which are raised upon each of the faces of the primitive octagon. Its integrant molecule, according to Hauy, is a regular tetrahedron.—For a more particular account of the crystals of this mineral, the reader is referred to Romé de Lisle[*], Hauy[†], and Professor Jameson[‡].

Crystals.

The crystals are commonly small. Their surface is smooth or streaked, except when the mineral occurs in grains, when it is rough or at least uneven. External lustre[§] 4 to 1; internal always 4. Fracture straight fo-

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[*] *Crystallog.* ii. 191.

[†] *Jour. de Min.* No. xxix. 343.

[‡] *Mineralogy*, i. 22.

[§] To save room, the degree of lustre is denoted by figures, as follows:

Splendent by - -	4
Shining - - - -	3
Glistening - - -	2
Glimmering - -	1
Dull - - - - -	

liated. Cleavage fourfold, parallel to the faces of the octahedron. Fragments octahedral or tetrahedral. Seldom occurs in distinct concretions. Transparency 4 to 2. Causes single refraction. Hardness 20. Brittle. Frangibility 3. Specific gravity 3·5185 to 3·5310 [*]. When rubbed it becomes positively electric, even before it has been cut by the lapidary, which is not the case with any other gem [†].

II. Zircon Family.

The minerals belonging to this family approach the nearest to the diamond in their external characters. Werner has divided them into three species; but other mineralogists have ranked these subdivisions merely as varieties. These species are *zircon*, *hyacinth*, and *cinnamon-stone*. They occur chiefly in the warm climates, especially Ceylon; though most of them have been found also in the northern regions.

Sp. 1. *Zircon.*

This mineral is usually brought from Ceylon; but it has been found lately in Norway.

Its usual colour is grey; but it occurs also green, blue, red, yellow, and brown. It is found most commonly in roundish pieces; but it is sometimes crystallized, either in four-sided prisms or flat octahedrons. The primitive form of its crystals is an octahedron,

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[*] Hauy, *Jour. de Min.* No. xxix. 343.

[†] Ibid. 343.

Zircon Family.

composed of two four-sided pyramids applied base to base, whose sides are isosceles triangles*. 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 crystals are usually small, their surface smooth, and their lustre 3; but the roundish pieces are sometimes rough, and their lustre 2. The internal lustre is 4.

The fracture foliated with a six-fold cleavage according to Mohs. Fragments sharp-edged. Transparency 2, 3. Causes a very great double refraction. Hardness 16. Brittle. Frangibility 3. Specific gravity 4·615 ‡ to 4·700 §.

Sp. 2. *Hyacinth.*

This mineral, which approaches the preceding so nearly that it ought to be considered as only a variety, is brought from Ceylon, but found likewise in France and in other parts of Europe.

Its usual colour is a hyacinth red, but it occurs also reddish brown, grey, and orange yellow. The primitive form of its crystals is the same as preceding. It usually occurs in four-sided prisms, terminated by four planes set on the lateral edges. The crystals are commonly small, but complete. Lateral planes smooth.

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* According to Mohs it has a six-fold cleavage, and its primative form is a four-sided rectangular prism, terminated by four-sided pyramids set on the lateral edges. This is also the most common variety of its crystallization.

† Hauy, *Jour. de Min.* No. xxvi. 91.

‡ Klaproth, *Beiträge*, i.

§ Werner, Jameson's *Mineralogy*, i. 30.

Lustre 3. Internal lustre 4, and vitreous. Fracture straight foliated. Cleavage as in the preceding species. Fragments sharp-edged. Transparency 4 to 2. Scratches quartz. Frangibility 3. Feels a little greasy when cut. Before the blow-pipe loses its colour, but not its transparency. Infusible with soda or microcosmic salt. Melts with borax into a transparent glass.

Sp. 3. *Cinnamon-stone* *.

This mineral, which like the rest is found in Ceylon, received its name from the Dutch, on account of its resemblance to cinnamon. It has been lately distinguished as a particular species by Werner. Colour yellowish brown, approaching to honey yellow. Occurs usually in splintery fragments. Fracture imperfect small conchoidal. Internal lustre 3, between resinous and vitreous. Fragments sharp-edged. Transparency from 4 to 2. Hard. Moderately heavy. Melts before the blow-pipe.

The constituents of these minerals, as determined by the analyses of Klaproth and Vauquelin, are as follows:

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* Jameson's *Mineralogy*, ii. 527.

Constituents.

	Zircon.		Hyacinth.			Cinnamon-stone.
	*	†	‡	§	§	‖
Zirconia	69·0	65	70	64·5	66	28·8
Silica....	26·5	33	25	32·0	31	42·8
Alumina						8·0
Lime						3·8
Iron oxide	0·5	1	0·5	2·0	2	3·0
Potash ...						6·0
Loss	4·0	1	4·5	1·5	1	7·0
	100	100	100	100	100	100·0

III. Chrysolite Family.

Chrysolite Family.

The species belonging to this family are six; namely, *chrysoberyl*, *chrysolite*, *olivine*, *coccolite*, *augite*, *vesuvian*. They all have a considerable resemblance to each other, especially in colour, fracture, and specific gravity.

Sp. 1. *Chrysoberyl*¶.

Cymophane of Hauy—*Chrysopal* of Delametherie.

Hitherto this stone has been found only in Brazil, the 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,

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[*] Klaproth's *Beitrage*, i. 222.

[†] From Norway. Ibid. iii. 271.

[‡] From Ceylon. Ibid. i. 231.

[§] From Expailly. Vauquelin, *Jour. de Min.* No. xxvi. 106.

[‖] Lampadius, Gehlen's *Jour.* Second series, ii. 53.

[¶] Kirwan, i. 262.—Brochant, i. 167.—Hauy, ii. 491.—Jameson, i. 38.

but it is sometimes also crystallized. The primitive form of its crystals is a four-sided rectangular prism, whose height is to its breadth as √3 to 1, and to its thickness as √2 to 1. The most common variety hitherto observed is an eight-sided prism, terminated by six-sided summits. Two of the faces of the prisms 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 prizm are wanting, and small faces in their place *.

Colour asparagus green, sometimes passing on the one hand to greenish white, and on the other to yellowish grey. External lustre of the crystals 3; internal 4, vitreous. Fracture perfect conchoidal. Fragments sharp-edged. Transparency 3. Scratches quartz. Brittle. Frangibility 3. Specific gravity from 3·60 to 3·798. Infusible before the blow-pipe.

Sp. 2. *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, found principally in Upper Egypt, is the *topaz* of the ancients; their chrysolite is now called *topaz* ‡.

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* Hauy, *Jour. de Min.* No. xxi. 5.

† Kirwan, i. 262.—Cartheuser, *Min.* 94.—Dolomieu, *Jour. de Min.* No. xxix. 365.—La Metherie, *Nouv. Jour. de Phys.* i. 397.—Brochant, i. 170.—Hauy, iii. 198.—Jameson, i. 42.

‡ Plinii Lib. xxxvii. c. 8.

Chrysolite Family.

Crystals.

The chrysolite is found in angular fragments, in grains, and crystallized. The primitive form of its crystals is a right-angled parallelopiped, whose length, breadth, and thickness, are as 5, $\sqrt{8}$, $\sqrt{5}$[*]. The edges of the prism are usually truncated. The lateral planes are longitudinally streaked.

Properties.

Colour pistachio green, sometimes approaching olive green, grass green, or even broccoli brown. External lustre of the crystals 4; internal 4, and vitreous. Fracture perfect conchoidal. Fragments sharp-edged. Transparency 4. Causes double refraction. Hardness 9. Brittle. Frangibility 4. Specific gravity from 3·410 to 3·440. 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[§].

Sp. 3. *Olivine*[‖].

This species has been united with the preceding by Hauy, on account of the sameness of the primitive form of the crystals. It occurs chiefly in basalt, and is very common, usually in roundish pieces or grains, though sometimes crystallized in rectangular four-sided prisms.

Colour intermediate between asparagus and olive green. Internal lustre 3; resinous. Fracture imper-

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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.

[‖] Kirwan, i. 263.—Lelievre, *Jour. de Phys.* xxx. 397.—Brochant, i. 175.—Jameson, i. 46.—Hauy, iii. 205.

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fect small conchoidal. Fragments sharp-edged. Often in small-grained distinct concretions. Transparency 3. Frangibility 5. Hardness 9. Specific gravity 3·225[*] to 3·265[†]. Nitric acid dissolves its iron[‡], and deprives it of its colour. Infusible before the blow-pipe. Melts with borax into a dark green bead.

Sp. 4. *Coccolite*[§].

This is one of the new minerals discovered by Dandrada during his travels in Sweden and Norway. It was found in the iron mines in Sudermannland, and at Arendahl.

Colour mountain, grass, and olive green. Massive. Internal lustre; vitreous. Fracture foliated. Cleavage single, according to Dandrada; but Hauy discovered, in the specimen he examined, that it was double. Composed of large and small granular concretions; some of which affect the form of four-sided prisms, and, according to Hauy, approach the primitive form of *augite*. Transparency 2. Streak greyish white. Scratches glass, and gives a few sparks with steel. Specific gravity 3·316[||] to 3·3739[¶]. Infusible before the blow-pipe. With carbonate of potash melts into an olive green vesicular glass; with borax into a pale yellow transparent glass.

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[*] Werner. [†] Klaproth. [‡] Kirwan, i. 264

[§] Dandrada, Nicholson's *Quarto Jour.* v. 195. Jameson, ii 528. Hauy, iv. 355. Brochant, ii. 504.

[||] Drandada. [¶] Hauy.

Sp. 5. *Augite*[*].

Pyroxene of Hauy—*Volcanite* of Delametherie—*Octahedral Basaltine* of Kirwan.

This mineral is found in basalt. It is sometimes in grains, but most commonly in crystals. The primitive form of its crystals is an oblique angled prism, whose bases are rhombs with angles of 92° 18′ and 87° 42′[†]. It is generally crystallized in six or eight sided prisms, terminated by dihedral summits[‡]. Crystals mostly small, but complete.

Colour blackish green, sometimes passing into leek green, and rarely to liver brown. Internal lustre 3, resinous. Fracture uneven, passing into imperfect small conchoidal. The crystals pass into perfect foliated with a double cleavage. Fragments sharp-edged. Transparency 2. Hard. Frangibility 3. Specific gravity from 3·2265[§] to 3·4771[‖]. Before the blow-pipe it is with difficulty converted into a black enamel.

Sp. 6. *Diopside*[¶].

Mussite and *Alalite* of Bonvoisin.

This mineral occurs in the Piedmontese Alps, and was discovered by Bonvoisin, and described by him in the Journal de Physique for May 1806. Specimens of it were sent to Paris, where it was examined by Hauy; and from its peculiar characters constituted by him into

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[*] Kirwan, i. 219.—Brochant, i. 179.—Hauy, iii. 80.—Jameson, i. 50.

[†] Hauy, *Jour. de Min.* xxviii. 269.

[‡] De Lisle, ii. 398.

[§] Hauy.

[‖] Werner.

[¶] Hauy and Tonnelier, Nicholson's *Jour.* xxii. 14.

a new species, under the name of *diopside*, from the appearance of its primitive crystals. For the only description of it which I have seen, we are indebted to Mr Tonnelier, keeper of the cabinet of mineralogy to the council of mines in Paris.

It occurs sometimes amorphous, but most commonly crystallized. Its primitive form is a right-angled quadrangular prism, with oblique bases. The angle of incidence between the diagonal of the base and the edge of the prism, at which it terminates, is 107° 8′. The prism is subdivisible by very clean sections in the direction of the diagonals of its base. The principal varieties of the crystals are, 1. the primitive form; 2. a didodecahedral crystal consisting of a twelve-sided prism, terminated at each extremity by six faces, situated two and two, one above the other. Sometimes it is compact, and sometimes in cilindroid prisms. The crystals of the variety called *mussite* are small, elongated, and commonly opaque. Those of the variety called *alalite* are larger, translucid, and of a greenish white colour. Colour green, greenish grey, greenish white, and yellowish white. Lustre not mentioned. Fracture appears to be foliated. Transparency 0 to 2 or 3. It scarcely scratches glass, but it scratches fluate of lime. Specific gravity 3·2374. Before the blow-pipe it fuses into a glass of the same greenish colour as the mineral itself.

Sp. 7. *Vesuvian*[*].

Hyacinthine of Delametherie—*Idocrase* of Hauy.

This mineral is found among the exuviæ of mount

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[*] Brochant, i. 184.—Hauy, ii. 574.—Jameson. i. 54.

Chrysolite Family.

Vesuvius, in a rock composed of *mica, hornblende, garnet*, and *calcareous spar*. It was formerly confounded with the hyacinth.

Colour olive green, sometimes passing into blackish green, sometimes into liver brown. Massive, and often crystallized in four-sided rectangular prisms, having the edges truncated. Its primitive form is a four-sided rectangular prism, little different from a cube, divisible in the direction of the diagonals of the base. Integrant molecule, a triangular prism [*]. Lateral planes of the crystals slightly streaked. Crystals short, and usually small. External lustre 3 ; internal 2, between vitreous and resinous. Fracture small grained, uneven. Has a tendency to small grained distinct concretions. Transparency 2. Scratches glass. Specific gravity from 3·0882 to 3·409 [†]. With borax it melts into a yellowish glass, which appears red while hot [‡].

Constituents.

THE composition of the minerals belonging to the chrysolite family, according to the most accurate analyses hitherto made, is as follows :

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[*] Hauy, ii. 574.

[†] Hauy.

[‡] Vauqueli .

	Chrysoberyl.	Chrysolite.		Olivine.		Coccolite.	Augite.			Vesuvian.	
	*	†	‡	§	‖	¶	**	††	‡‡	§§	‖‖
Alumina	71·5					1·5	3·33	3·05	7·25	22·25	16·25
Silica	18·0	39·0	38·0	50·0	52·00	50·0	52·00	54·00	52·5	35·50	42·00
Magnesia		43·5	50·5	38·50	37·75	10·0	10·00	14·00	12·5		
Lime	6			0·25	0·12	24·0	13·20	16·20	9·0	33·00	34·00
Iron oxide	1·5	19·0	9·5	12·00	10·75	7·0	14·66	7·00	16·25	7·50	5·50
Mang. ox.						3·0	2·00			0·25	
Potash								5·18	0·5		
Loss	3		2			4·5	4·81	0·57	2	1·50	2·25
	100·0	101·5	100·0	100·75	100·62	100·0	100·0	100·0	100·0	100·0	100·0

From these analyses, it appears that all the species contain a considerable proportion of silica. Iron also enters into the composition of each; but the other ingredients vary. The composition of the augite and coccolite approach so closely to each other, as well as their external characters, that they will probably turn out to be only varieties of the same species. The olivine and chrysolite differ chiefly in the proportions of the silica and magnesia.

IV. GARNET FAMILY.

THE species belonging to this family are five; name-

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* Klaproth's *Beitrage*, i. 102. † Klaproth, Ibid. p. 110.

‡ Vauquelin, *Ann. de Chim.* xxi. 97.

§ From Unkel. Klaproth, Ibid. p. 118.

‖ From Karlesberge. Klaproth, Ibid. p. 121.

¶ Vauquelin, Hauy, iv. 357.

** Vauquelin, *Jour. de Min.* No. xxxix. 172.

†† Trommsdorf, Gehlen's *Jour.* i. 382.

‡‡ Foliated augite from the south Alps. Klaproth, *Beitrage*, iv. 185.

§§ Klaproth, *Beitrage*, ii. 32. ‖‖ Ibid. p. 38.

ly, *leucite*, *melanite*, *garnet*, *staurolite*, *pyrope*. They all bear a strong resemblance to each other in the figure of their crystals, which is almost always complete.

Garnet Family.

Sp. 1. *Leucite* *.

Vesuvian of Kirwan—*White Garnet* of Vesuvius—
Amphigene of Hauy.

This stone is usually found in volcanic productions, and is very abundant in the neighbourhood of Vesuvius. 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 spheroidal 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.

Colour yellowish and greyish white; very seldom reddish white. Internal lustre 3, vitreous. Fracture imperfect flat conchoidal, sometimes inclines to foliated. Fragments sharp-edged. Transparency, 2, 3. Scratches glass with difficulty. Brittle. Frangibility 4. Specific gravity from 2·455 to 2·490 ‡. Its powder causes syrup of violets to assume a green colour §. Infusible by the blow-pipe. Gives a white transparent glass with borax.

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* Kirwan, i. 285.—Brochant, i. 188.—Hauy, ii. 559.—Jameson, i. 57.

† *Jour. de Min.* No. xxvii. 185.

‡ Klaproth, *Beitrage*, ii. 41, and 55.

§ Vauquelin, *Jour. de Min.* No. xxxix. 165.

Sp. 2. *Melanite*[*].

Black Garnet.

This mineral, which has hitherto been found only at Frescati and St Albano, near Rome, was long confounded with *garnet*. It was first accurately distinguished by Werner.

Its colour is velvet black, sometimes inclining to greyish black. It is usually in complete crystals. They consist of six-sided prisms accuminated by three planes, which are placed on the alternate lateral edges. Surface smooth. Lustre 3. Fracture imperfect flat conchoidal. Fragments sharp-edged. Opaque, Hard. Frangibility 4. Specific gravity from 3·691[†] to 3·800[‡].

Sp. 3. *Garnet*[§].

Crystals.

This mineral occurs abundantly in primitive mountains. 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 dodecahedron 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

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[*] Brochant, i. 191.—Jameson, i. 61.

[†] Karsten.

[‡] Werner.

[§] Kirwan, i. 258.—Gerhard, *Disquisitio Physico-chymica Granatorum*, &c.—Pasumot, *Jour. de Phys.* iii. 442.—Wiegleb, *Ann. de Chim.* i. 231.—Brochant, i. 195.—Hauy, ii. 340.—Jameson, i. 64.

[‖] Romé de Lisle, ii. 322. and Hauy, *Ann. de Chim.* xvii. 305.

Garnet Family.

the dodecahedron are divided by their shorter diagonal. The integrant molecules of garnet are similar tetrahedrons *. Sometimes the edges of the dodecahedrons 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 †.

Werner divides this species into two subspecies; namely, the *precious* and *common* garnet. They are distinguished from each other by colour, lustre, fracture, distinct concretions, transparency, and specific gravity.

Subspecies 1. *Precious Garnet.*

This is supposed by some to be the *carbuncle* of the ancients. It is employed in jewellery.

Colour *red*. Hence the name of the mineral, from its supposed resemblance to the flower of the pomegranate. Passes from columbine red to cherry and brown red. Commonly crystallized, and the crystals are always complete: sometimes in round grains. External lustre 2; internal 3, 2, vitreous. Fracture perfect conchoidal, sometimes inclining to coarse-grained uneven. Fragments sharp-edged. Sometimes in lamellar distinct concretions. Transparency from 4 to 2. Scratches quartz. Brittle. Frangibility 3. Specific gravity from 4·085 ‡ to 4·352 §.

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* Hauy, Ibid. 306.

† Hauy, *Ann. de Chim.* xvii. 306.

‡ Klaproth.

§ Karsten.

Subspecies 2. Common Garnet.

Colour, various shades of brown and green ; namely, liver, yellowish and reddish brown ; olive, pistachio, blackish, and leek green ; Isabella yellow ; blood red ; greenish black. Different colours often appear in the same mass. Massive, but never in grains or angular pieces ; sometimes crystallized. Surface of the crystals diagonally streaked. External lustre 3, 2 ; internal 2, between resinous and vitreous. Fracture fine-grained uneven. Fragments not sharp-edged. In small-grained distinct concretions. Transparency 2 ; black varieties nearly opaque. Frangibility 4. Specific gravity from 3·668 [*] to 3·757 [†]. Melts before the blow-pipe more easily than the first subspecies.

Sp. 4. *Granatite* [‡].

Staurotide of Hauy—*Pierre de Croix* of de Lisle—
Staurolithe of Lametherie.

Crystals.

Granatite is found in Galicia in Spain, Britanny in France, and at St Gothard. 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

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[*] Karsten. [†] Werner.

[‡] Brochant, ii. 496.—Hauy, iii. 93.—Jameson, i. 76.

[§] Romé de Lisle, ii. 435.

Garnet Family.

to the greater diagonal of the rhomb as one to six; 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*.

Colour dark reddish brown. Surface sometimes smooth, sometimes uneven. Internal lustre 2; between vitreous and resinous. Fracture between small-grained uneven, and imperfect conchoidal. Transparency often 0, sometimes 2. Scratches quartz feebly. Brittle. Frangibility 4. Specific gravity 3·2861. Infusible before the blow-pipe.

Sp. 5. *Pyrope* †.

This mineral which is found in Bohemia, and was formerly distinguished by the name of Bohemian garnet, 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 small.

Colour dark blood red, which when held between the eye and the light, inclines strongly to yellow. Lustre 4, vitreous. Fracture perfect conchoidal. Fragments sharp-edged. Transparency 4. Scratches quartz. Specific gravity 3·718 ‡ to 3·941 §.

Constituents.

The constituents of the preceding species, according to the most exact analyses hitherto made, are as follows:

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* *Ann. de Chim.* vi. 142.

† Jameson, i. 73.

‡ Klaproth.

§ Werner.

	Leucite.		Melanite.	Precious Garnet.		Common Garnet.			Granatite.		Pyrope.
	*	†	‡	§	‖	¶	¶	**	††	††	§§
Silica	54	56	35	35·75	36	38	43	44·0	33	30·6	40
Alumina	24	20	6·4	27·25	22	20	16	8·5	44	47·0	28·5
Lime		2	32		3	31	20	33·5	3·84	3·0	3·5
Magnesia											10
Iron oxide			25·5	36·00	41	10	16	12·0	13	15·3	16·5
Mang. ox.			Trace	0·25				Trace	1		0·25
Potash	21	20									
Water,&c.							4				
Loss	1	2	1·1	0·75		1	1	2·0	5 16	4·1	1·25
	100	100	100	100	102	100	100	100	100	100	100

From these analyses, it appears that all the species contain a considerable proportion of silica and alumina. These with potash and a little lime constitute the leucite. Granatite seems likewise to contain potash; and besides the constituents of leucite, it contains a considerable proportion of iron. In the common garnet the constituents are the same; but the proportion of lime is considerably increased, while that of the alumina is diminished. Pyrope differs from all the rest in containing magnesia.

V. RUBY FAMILY.

The minerals belonging to this family are divided into six species, namely, *ceylanite*, *spinell*, *sapphire*,

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* Klaproth, *Beitrage*, ii. 50.

† Vauquelin.

‡ Vauqnelin, Hauy, ii. 543.

§ Klaproth, *Beitrage*, ii. 26.

‖ Vauquelin, Hauy, ii. 542.

¶ Vauquelin, Ibid.

** Olive green garnet from Siberia. Klaproth, *Beitrage*, iv. 319.

†† Vauquelin, *Jour. de Min.* No. liii. 353; and *Ann. de Chim.* xxx. 104.

§§ Klaproth, *Beitrage*, ii. 21.

Ruby Family.

emery, *corundum*, and *adamantine spar*. They are all extremely hard, and several of them highly valued on account of their beauty.

Sp. 1. *Ceylanite* *.

Pleonaste of Hauy.

The mineral denominated *ceylanite*, from the island of Ceylon, from which it was brought into Europe, had been observed by Romé de Lisle †; but was first described by La Metherie in the *Journal de Physique* for January 1793.

It is most commonly found in rounded masses; but sometimes also crystallized. The primitive form of its crystals is a regular octahedron: it often occurs under this form, but more commonly the edges of the octahedron are wanting, and small faces in their place ‡.

Colour appears dark indigo blue, passing into bluish black; but when closely examined proves greenish black. Surface rough. External lustre 0 nearly; internal 3, 4, resinous. Fracture perfect flat conchoidal. Fragments very sharp-edged. Scratches quartz slightly. Frangibility 4. Specific gravity from 3·7647 to 3·7931 §. Infusible *per se*.

Sp. 2. *Spinell* ||.

Spinel and *balass ruby* of Kirwan—*Rubis spinelle octoedre of* De Lisle—*Spinellus* of Gmelin.

This stone, which comes from the island of Ceylon,

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* Brochant, ii. 525.—Hauy's *Miner*. iii. 17.—Bournon, *Phil. Trans*. 1802, p. 318.—Jameson, ii. 531.

† *Crystallog*. iii. 180. Note 21.

‡ Hauy, *Jour. de Min*. No. xxxviii. 164.

§ Hauy.

|| See Kirwan's *Min*. i. 253.—Romé de Lisle, ii. 224.—Klaproth, *Be-*

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*[*]. It occurs also in tetrahedrons, in rhomboids whose faces have angles of 120° and 60°, in rhomboidal dodecahedrons, and in four-sided prisms terminated by four-sided pyramids[†].

Colour red, passing on the one side to blue, and on the other to yellow and brown. From carmine red it passes into crimson, cochineal, and cherry red; and into plum, violet, and indigo blue; and likewise into blood red, orange yellow, and reddish brown. Surface smooth. Lustre 4, vitreous. Fracture perfect flat conchoidal, sometimes imperfectly foliated. Fragments sharp-edged. Transparency from 2 to 4. Scratches quartz strongly. Scratched by sapphire. Specific gravity from 3·570[‡] to 3·700[§]. Infusible before the blow-pipe: melts with borax. The ancients seem to have classed this stone among their hyacinths[||].

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ob, der Berlin, iii. 336. and Beitrage, ii. 1.—Vauquelin, *Ann. de Chim.* xxvii. 3. and xxxi 141.—Brochant, i. 202.—Hauy, ii. 496.—Bournon, *Phil. Trans.* 1802, p. 304.—Jameson, i. 78.

[*] *Crystall.* ii. 226.—Estner's *Miner.* 73.

[†] Bournon.

[‡] Klaproth.

[§] Werner.

[||] Plinii lib. xxxvii. c. 9.

Ruby Family.

Sp. 3. *Sapphire.*

History.

The stones usually called precious were first distinguished on account of their colour. Those that had a red colour were called *rubies ;* the yellow were *topazes ;* the blue, *sapphires ;* and the purple, *amethysts.* It was soon observed, however, that most of the properties for which these stones were valued were proportional to their hardness ; and as the finest kind came from the East, it was usual with lapidaries to distinguish them by the epithet *oriental.* Mineralogists were accustomed to consider these stones as distinct species, till Romé de Lisle observed that they agreed in the form of their crystals, their hardness, and most of their other properties ; and Werner made the same remark about the same time. 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 been since confined to a different mineral. This induced Hauy to invent the new word *telesia ;* but the term *sapphire,* appropriated to this species by Werner and Delametherie, was adopted by mineralogists in general.

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, as has been demonstrated by Bournon, is a rhomboid, whose angles are 86° and 94°, and which therefore is nearly rectangular. Sometimes it occurs in this form, though but seldom. Bournon has described no less than eight modifications of it.

We may consider the primitive form as composed of two trihedral pyramids united base to base, the solid angles of which are composed of three acute angles of the faces. The eight modifications are, 1. The summit of the pyramids is replaced by a face perpendicular to the axis, and of various sizes. 2. The edges of the base of the primitive pyramids are replaced by faces parallel to the axis, which separates the pyramids by a six-sided prism with rhombic planes. Often this modification runs into a regular six-sided prism. 3. A decrement takes place on the flat angles of the base, which converts the pyramids to six-sided, so that the crystal is often a dodecahedron, composed of two six-sided pyramids applied base to base; but it is very seldom that both pyramids are complete. This modification is often combined with the second. 4. The solid angle at the summit is replaced by three faces, which sometimes become so large as to cause the faces of the primitive rhomboid to disappear, and converts the crystal into a secondary rhomboid, whose faces have angles of 114° and 66°. 5. A more rapid decrement of the same kind produces a rhomboid still more acute, the faces of which have angles of 117° and 63°. 6. Similar decrements, still more rapid, form a third rhomboid still more acute, whose faces have angles of 119° 14′ and 60° 46′. 7. The acute angles which rest upon the base of the primitive pyramids suffer a decrement, which converts the crystal into a six-sided prism, whose faces correspond with the solid angles of the base of the primitive pyramids. 8. A six-sided pyramid, the solid angle of whose summit measures 24°. Each of the edges of the pyramid is replaced by a small face, which makes the pyramid a dodecahedron [*]. The crystals are complete; planes often transversely streaked. Occurs often in small rolled pieces.

Colours blue and red. From Berlin blue it passes into indigo blue, and into azure, violet, lavender, lilac, and sky blue, and deep green: from lilac blue into peach blossom, crimson, cochineal, and carmine red; also into rose red, reddish white, and yellowish white; from lavender blue into pearl and bluish grey, and bluish white. Lustre 4, vitreous. Fracture conchoidal. Transparency from 4 to 2. Causes only single refraction. Harder than all minerals, except the diamond. Frangibility 4. Specific gravity from 4·000 to 4·083 [†]. Infusible before the blow-pipe. Melts with borax without effervescence.

Sp. 4. *Emery* [‡].

This mineral is brought to Britain from the isle of Naxos, where it must exist in great abundance. It occurs also in Germany, Italy, and Spain. It is always in shapeless masses, and mixed with other minerals. It has been usually considered as an iron ore, because it is always contaminated with the oxide of that metal. Colour intermediate between greyish black and bluish grey. Lustre, 2, 1. Adamantine. Fracture small-grained uneven, sometimes splintery. Fragments rather blunt-edged. Sometimes in fine grained distinct concretions. Transparency 0. Scarcely yields to the file. Frangibility 2. Specific gravity about 4. This mineral is much used in polishing hard bodies.

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[*] *Phil. Trans.* 1802, p. 250.

[†] Hatchet and Greville.

[‡] Jameson, i. 96.

Sp. 5. *Corundum*[*].

Corundum of Gmelin—*Adamantine spar* of Klaproth and Kirwan—*Corindon* of Hauy—*Corivindum* of Woodward.

History.

Though *corundum* appears to have been known to Dr Woodward, it may be said to have been first distinguished from other minerals by Dr Black. In 1768, Mr Berry, a lapidary in Edinburgh, received a box of it from Dr Anderson of Madras. Dr Black ascertained that these specimens differed from all the stones 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 of Madras, in a rocky matrix, of considerable hardness, partaking of the nature of the stone itself[†]. It occurs also in China, and in Ceylon, Ava, &c. The Count de Bournon pointed out the resemblance between this mineral and the sapphire, in a dissertation published by him and Mr Greville in the Philosophical Transactions for 1798, and suggested it as probable

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[*] See Kirwan's *Min.* i.—Klaproth *in Beob. der Berlin*, viii. 295. and *Beitrage*, i. 47.—Mr Greville and the Count de Bournon in the *Philosophical 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. and *Mineral.* iii. 1.—Brochant, i. 356.—Jameson, i. 90.

[†] Garrow and Greville, Nicholson's *Jour.* ii. 540.

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. This conjecture has been since confirmed by a subsequent dissertation of Bournon, and the chemical analysis of Chenevix *. Werner subdivides it into two species, namely *corundum* and *adamantine spar;* but in reality they seem to be only varieties, or at most subspecies of the same species. The chief difference exists in the colours.

Corundum has been found in India, in the Carnatic, and on the coast of Malabar. It occurs massive, in rolled pieces, and crystallized. Crystals the same as in sapphire. Colour greenish white, passing into greenish grey and asparagus green; sometimes pearl grey, which passes into flesh red. Surface rough. External lustre 0; internal 3, 2, vitreous. Fracture foliated. Cleavage threefold. Fragments rhomboidal. Transparency 2. Scratches quartz. Frangibility 4. Specific gravity 3·710 † to 4·180 ‡.

Sp. 6. *Adamantine Spar* §.

This mineral has hitherto been found only in China. Colour dark hair brown. Massive, in rolled pieces, and crystallized in six-sided prisms and six-sided pyramids, having their apex truncated. Internal lustre 4, pearly. Fracture foliated. Fragments rhomboidal. Transparency 1. Hard. Frangibility 4. Specific gravity 3·981 ||.

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* *Phil. Trans.* 1802, p. 233.

† Klaproth.

‡ Greville, Nicholson's *Jour.* iii. 11.

§ Jameson, i. 93.

|| Klaproth.

Constituents.

The following Table exhibits the constituents of the minerals belonging to the ruby family, according to the most exact analyses hitherto made :

	Ceylanite.	Spinell.		Sapphire.			Emery.	Corundum.			Adamantine Spar.	
	*	†	‡	§	‖	¶	**	††	‡‡	‡‡	‖‖	¶¶
Alumina	68	74·5	82·47	98·5	92	90	86	89·5	91	86·5	84	86·5
Silica	2	15·5			5·25	7	3	5·5	5	7	6·5	5·25
Magnesia	12	8·25	8·78									
Iron oxide	16	1·5		1·0	1·0	1·2	4	1·25	1·5	4	7·5	6·5
Chromic oxide			6·57									
Lime		0·75		0·5								
Loss	2		2·18		1·75	1·8	7	3·75	2·5	2·5	2	1·75
	100	100·5	100	100	100	100	100	100	100	100	100	100

* Descotils, *Ann. de Chim.* xxxiii. 11.

† Klaproth, *Beitrage*, ii. 10.

‡ Vauquelin, *Jour. de Min.* No. xxxviii. 89.

§ Klaproth, *Beitrage*, i. 88.

‖ Blue variety, Chenevix, *Phil. Trans.* 1802.

¶ Red variety, Chenevix, Ibid.

** Tennant, *Phil. Trans.* 1802. p. 400.

†† Klaproth, *Beitrage*, i. 77.

‡‡ Chenevix, *Phil. Trans.* 1802, First specimen from the Carnatic, second from Malabar.

‖‖ Klaproth, *Beitrage*, i. 73.

¶¶ Chenevix, *Phil. Trans.* 1802.

Except the ceylanite and spinell, which are distinguished by containing magnesia, the composition of all these minerals is extremely similar; indeed sufficiently so, especially when joined with the external characters, to constitute them only a single species.

Automolite.

There is a very singular mineral lately analysed by Eckeberg, under the name of *automolite*, which, from the imperfect description which he has given, appears to approach the spinell and ceylanite in its properties.

Its colour is dark green. Always crystallized in regular octahedrons, similar to the form of the spinell. The crystals are small. Longitudinal fracture foliated; cross fracture uneven and somewhat conchoidal. Transparency in small pieces 2. When pounded, it becomes light green. Specific gravity 4·261. Not fusible by the blow-pipe. With borax it melts into a glass green while hot, but colourless when cold. Its constituents are,

	*	†
Alumina.........	60	42
Silica.............	4·75	4
Zinc oxide.......	24·25	28
Iron oxide.......	9·25	5
Sulphur and loss		17
Loss..............	1·75	
Undecomposed		4
	100	100

Topaz Family.

VI. Topaz Family.

The topaz, like the diamond, differs very much in its external characters from all other minerals, and

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* Eckeberg, Gehlen's *Jour.* v. 443.

† Vauquelin, Gehlen's *Jour.* Second series, ii. 38.

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therefore must at present constitute a family apart. It contains only one species; namely, the common topaz.

Sp. 1. *Topaz* *.

Occidental ruby, topaz, and *sapphire.*

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*, derived 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 six. Five of these are eight-sided prisms, terminated by four-sided pyramids, or wedge-shaped summits, or by irregular figures of 7, 13,

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[*] 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.—Brochant, i. 212.

[†] It got its name from *τοπαζω, to seek;* because the island was often surrounded with fog, and therefore difficult to find. See Plinii lib. xxxvii. c. 8.

[‡] Hauy, *Jour. de Min.* No. xxviii. 287.

Topaz Family.

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 [*]. The lateral planes of the crystals are longitudinally streaked; the other planes are smooth.

Colour wine yellow. From pale wine yellow it passes into yellowish white, greenish white, mountain green, sky blue: from deep wine yellow into flesh red and crimson red. Lustre 4, vitreous. Cross fracture perfect straight foliated; longitudinal, small imperfect conchoidal. Fragments sharp-edged, sometimes tabular and splintery. Transparency from 2 to 4. It causes a double refraction. Hardness 12 to 14. Frangibility 4. Specific gravity from 3·464 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. This shows us that the colouring matter of these two stones is different.

Constituents.

The composition of this mineral is very remarkable. The first accurate analysis of it was published by Lowitz; but there was a loss of 7 *per cent.* which he could not account for. Klaproth repeated the analysis, and found the loss owing to a quantity of fluoric acid, which constitutes a part of the stone. The following is the result of two specimens analysed by this illus-

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[*] Hauy, *Jour. de Min.* No. xxviii. 287.

[†] Ibid.

trious chemist; the first was a Saxon topaz, the second a Brazilian*.

Alumina	59	47·5
Silica	35	44·5
Fluoric acid	5	7·0
Iron oxide	Trace	·5
Loss	1	·5
	100	100

These experiments were repeated by Vauquelin, who obtained a greater proportion of fluoric acid. The following Table exhibits the results of his trials †:

	Saxon Topaz.	Siberian.	Brazilian.	Ditto.
Alumina	49	48	47	50
Silica	29	30	28	29
Fluoric acid	20	18	17	19
Iron oxide		2	4	
Loss	2	2	4	2
	100	100	100	100

Pyrophysalite.

Messrs Hisinger and Berzelius have published a description and analysis of a mineral found by Gahn, at Finbo near Fahlun in Sweden, in a granite rock; to which they have given the name of *pyrophysalite*.

Colour white, sometimes with a shade of green, usually in irregular pieces, sometimes approaching to the shape of a rhomboid. Fracture foliated. The cleavage appears to be triple; but two of them, which are

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* Gehlen's *Jour.* iii. 592 and 595.

† Ibid. v. 481.

parallel to the sides of the rhomboid, are very indistinct; while the third parallel to the axis of the rhomboid is very well defined. Fragments indeterminate, sharp-edged. Transparency 1. Scratches glass readily, but is itself scratched by quartz. Difficultly frangible. Specific gravity 3·451. The powder phosphoresces slightly when heated. Scarcely fusible before the blow-pipe, but becomes white and opaque, and small bubbles cover its surface, which burst when the heat is kept up. With borax it melts into a transparent and colourless glass; with soda it effervesces, and forms a porous mass. According to the analysis of Hisinger and Berzelius its constituents are as follows *.

Alumina	53·5
Silica	32·88
Lime	0·88
Oxide of iron	0·88
Volatile matter	0·75
Loss	11·36
	100·00

Hauy has examined this mineral with his usual sagacity, and has satisfied himself that it is a variety of topaz †.

As a sufficient number of specimens of the two following minerals has not hitherto been examined to enable mineralogists to assign them a proper place, and as they agree nearly in their constituents with the topaz, they may be placed provisionally along with that mineral.

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* *Ann. de Chim.* lviii. 113.

† Nicholson's *Jour.* xxii. 20.

Sp. 2. *Fibrolite* [*].

This mineral was first observed by Bournon in the matrix of the imperfect corundum. Colour white or dirty grey. Hardness rather greater than that of quartz. Specific gravity 3·214. Texture fibrous. Cross fracture compact. Internal lustre glossy. Infusible by the blow-pipe. Usually in shapeless fragments. Bournon observed one specimen crystallized in a rhomboidal prism; the angles of whose faces were 80° and 100°. It is composed, according to Chenevix, of

58·25	alumina
38·00	silica
3·75	a trace of iron and loss
100·00 [†]	

Sp. 3. *Sommite* [‡].

Nepheline of Hauy—*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 greyish white. External lustre 3, vitreous. Longitudinal fracture foliated; cross fracture conchoidal. Transparency 2, 3. Frangibility 4. Cuts glass. Specific gravity 3·2741. Infusible by the blow-

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[*] Bournon, *Phil. Trans.* 1802, p. 289.

[†] Ibid. p. 335.

[‡] Brochant, ii. 522.—Hauy, iii. 186.—Jameson, ii. 565.

Schorl Family.

pipe. According to the analysis of Vauquelin, it is composed of
49 alumina
46 silica
2 lime
1 oxide of iron

98*

VII. Schorl Family.

This family comprehends eight species; namely, *euclase*, *emerald*, *beryl*, *schorlous beryl*, *schorl*, *pistazite*, *zoisite*, and *axinite*.

Sp. 1. *Euclase*†.

This stone, which has lately been brought from Peru by Dombey, was at first confounded with the emerald, on account of its green colour. It is always crystallized. The primitive form of its crystals is a rectangular prism, whose bases are squares; but it usually occurs in four-sided oblique prisms, whose edges are variously truncated.

The crystals are longitudinally streaked. Colour mountain green. Lustre 4, vitreous. Longitudinal fracture foliated. Cleavage twofold. Cross fracture conchoidal. Causes a double refraction. Scratches quartz. Frangibility 6. Specific gravity 3·0625. Fusible before the blow-pipe into a white enamel.

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[*] *Jour. de Min.* No. xxviii. 279.

[†] Brochant, ii. 508.—Hauy, ii. 531.—Jameson, ii. 533.

Sp. 2. *Emerald*[*].

Crystals.

This mineral comes chiefly from Peru; some specimens have been brought from Egypt. Dolomieu found it in the granite of Elba. Hitherto it has been found only crystallized. 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[‡].

Crystals short; lateral planes smooth, terminal planes rough. Colour emerald green of all intensities. Internal lustre between 3 and 4, vitreous. Fracture small imperfect conchoidal, with a concealed foliated fracture and four-fold cleavage. Fragments sharp-edged. Transparency 4 to 2. Causes double refraction. Scratches quartz with difficulty. Specific gravity from 2·600[§] to 2·7755[‖].

Sp. 3. *Beryl.*

This mineral is found embedded in primitive rocks and veins in many parts of the world, especially in Siberia. It is crystallized in the same forms as the eme-

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[*] Kirwan, i. 247 and 248.—Dolomieu, *Magazin Encyclopædique*, ii. 17 and 145; and *Jour. de Min.* No. xviii. 19.—Klaproth's *Beitrage*, ii. 12.—Brochant, i. 217.—Hauy, ii. 516.—Jameson, i. 105.

[†] Hauy, *Jour. de Min.* No. xix. 72.

[‡] Rome de Lisle, ii. 445. and Hauy, Ibid.

[§] Werner.

[‖] Hauy.

rald. The crystals are long, have their lateral planes longitudinally streaked, their terminal planes smooth.

Schorl Family.

Its most common colour is green; from mountain green, it passes into apple, asparagus, oil green, honey yellow; also into smalt and sky blue. The colours are usually pale. External lustre 3, 2; internal 3, vitreous. Cross fracture between uneven and small imperfect conchoidal: longitudinal fracture foliated, with a fourfold cleavage. Fragments sharp-edged. When massive it consists of thin prismatic distinct concretions. Transparency 4; sometimes 2, and then it exhibits cross rents. Causes double refraction. Nearly as hard as topaz. Frangibility 4. Specific gravity 2·650 to 2·759 [*].

Only a variety of the preceding.

These two minerals approach so nearly in their characters, that it would be better to arrange them, as Hauy has done, merely as subspecies. They become electric by friction, but not by heat. The powder does not phosphoresce when thrown on a hot iron [†]. At 150° Wedgewood they melt into an opaque coloured mass. According to Dolomieu, they are fusible *per se* by the blow-pipe [‡].

Sp. 4. *Schorlite* [§].

Schorlous beryl of Werner—*Leucolite* of Daubenton—*Pycnite* of Hauy.

This stone, which received its name from Mr Klaproth, is generally found in oblong masses, which when

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[*] Werner. [†] Dolomieu, *Jour. de Min.* No. xviii. 19. [‡] Ibid.

[§] Brochant, i. 224.—Hauy, iii. 236.—Jameson, i. 116.—Bucholz, Gehlen's *Jour.* ii 15.

Crystals.

regular are six-sided prisms inserted in granite. It is found at Altenberg in Saxony, in a primitive rock, and likewise in other places. By careful mechanical division, small four-sided prisms, whose bases are rhombs with angles of 120° and 60°, may be obtained from the larger specimens. These Bucholz considers as the primitive form of the schorlite. The crystals commonly large.

The colour is white of various shades, passing, on the one hand, through greyish white, and yellowish white, into straw yellow, and, on the other, through reddish white into peach blossom, and even crimson red. Some specimens are marked with spots of violet blue. Lustre 3, resinous. Cross fracture imperfect foliated; longitudinal imperfect small conchoidal. Composed of thin prismatic distinct concretions, which are longitudinally streaked. Transparency 2. Moderately hard. Brittle. Frangibility 6. Specific gravity from 3·503 to 3·530 *.

Werner considers this mineral as a subspecies of beryl; but neither the specific gravity, nor the primitive form of the crystals, will admit of this arrangement. It is remarkable for being the second stony mineral which was found to contain fluoric acid as a constituent. For the curious discovery of the presence of this acid in crystallized stones, we are indebted to Klaproth; Bucholz first found it in a hard crystal.

Sp. 5. *Schorl*†.

Tourmaline of Hauy.

The word *schorl* is said to be derived from the vil-

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* Bucholz.

† Kirwan, i. 265.—Hauy, iii. 31.—Brochant, i. 226.—Jameson, i. 120.

lage of Schorlaw in Saxony, where the mineral to which that name was originally given was first observed*.

History.

No word has been used by mineralogists with less limitation than *schorl*. 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 *schorl* almost 20 distinct species of minerals were included. Werner first defined the word *schorl* precisely, and restricted it to one species of stones. It occurs commonly in granite, gneiss, and other similar rocks; often massive but very frequently crystallized. Primitive form of its crystals is an obtuse rhomboid; the solid angle at the summit of which is 139°, having rhombic faces, with angles of 114° 12′ and 65° 48′: But it usually occurs in three, six, eight, nine, or twelve sided prisms, terminated by four or five sided summits, variously truncated; for a description of which the reader is referred to *Hauy* † and *Bournon* ‡. The faces of the crystals are often convex.

Werner divides this species into two subspecies, distinguished chiefly by their colour, and the situation in which they are found. The subdivision is in some respects convenient, as it shortens description, especially in that branch of mineralogy which Werner has distinguished by the name of *geognosy*.

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* Jameson's *Mineralogy*, i. 124.

† *Miner.* iii. 34.

‡ *Phil. Trans.* 1802, p. 313.

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Subspecies 1. *Common schorl.*

Colour velvet black. Found massive, disseminated, and crystallized. Crystals three-sided prisms, having their lateral edges truncated; sometimes terminating in a pyramid. The crystals are mostly acicular. Lustre 2, vitreous. Fracture conchoidal, between imperfect and small grained uneven. Opaque. Often composed of thin prismatic distinct concretions. Streak grey. Hardness rather inferior to quartz. Specific gravity from 3·054 to 3·092. When heated to redness, its colour becomes brownish red; and at 127° Wedgewood, it is converted into a brownish compact enamel *.

It often becomes electric when heated, precisely like the succeeding subspecies; but sometimes, from its containing particles of iron, the experiment does not succeed †.

Subspecies 2. *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. It is sometimes in amorphous pieces, but much more frequently crystallized in three or nine sided prisms, with four-sided summits.

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* Kirwan's *Min.* i. 166.

† Hauy, iii. 56.

|| 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 Sapphir, l'Oeil de Chat, et la Tourmaline de Ceylon, demasqués.*—Brochant, i. 288. Sir William Watson has shown that the *lyncurium* of the ancients, as described by Theophrastus, must have been the tourmaline. *Phil. Trans.* 1759. p. 394.

Schorl Family.

Principal colours *green* and *brown*. From leek green passes into pistachio and olive green; liver brown, yellowish and reddish brown; hyacinth and crimson red; violet, azure, berlin, and indigo blue. Found usually crystallized. Crystals three, six, or nine-sided prisms, variously truncated. Lateral faces usually striated longitudinally. Internal lustre 4, vitreous. Cross fracture has a tendency to foliated; longitudinal perfect conchoidal. Transparency from 0 to 4. Hard. Frangibility 4. Specific gravity from 3·0704 [*] to 3·155 [†].

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.

The *siberite* of Lermina, called *daourite* by Lametherie, a mineral found in Siberia, is considered as merely a variety of schorl.

Sp. 6. *Pistazite* [§].

Delphinite of Saussure—*Epidote* of Hauy—*Thallite* of Lametherie—*Acanticone, arendate* of Dendrada.

This mineral, which occurs in the fissures of mountains, was first observed in Dauphiny, afterwards in Germany, Norway, and other countries.

Crystals.

It occurs massive and crystallized. The primitive form of its crystals is a rectangular prism, whose bases are rhombs with angles of 114° 37′ and 65° 23′ [‖]. The

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[*] Hauy. [†] Werner. [‡] Æpinus.

[§] Brochant, i. 510.—Hauy, iii. 102.—Jameson, ii. 530.

[‖] Hauy, *Jour. de Min.* xxviii. 271.

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; longitudinally streaked. Internal lustre 3. Fracture sometimes foliated, sometimes variously radiated. Fragments sometimes wedge-shaped and splintery. In coarse granular distinct concretions. Transparency 2; sometimes 4. Hard. Frangibility 4. Specific gravity from 3·4529 to 3·46. Powder white or yellowish green, and feels dry. It does not become electric by heat. Before the blow-pipe froths and melts into a black slag. With borax it melts into a green bead †.

Sp. 7. *Zoisite* ‡.

This mineral has lately been introduced into the system by Werner, who named it from Baron Von Zois, the discoverer. It occurs in primitive mountains, and has been found in Carinthia and Baireuth, and likewise in Aberdeenshire in Scotland. Hauy considers it as a variety of *piztazite*.

Colour yellowish grey, sometimes smoke grey. Massive and crystallized in very oblique four-sided prisms, having their obtuse angles rounded off. Crystals longitudinally streaked. Internal lustre 3, inclining to pearly. Fracture foliated; in massive pieces, inclines to radiated. Only a single cleavage parallel to the shorter diagonal of the prism hitherto discovered. Shows

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* Rome de Lisle, *Crystall.* ii. 401. and Hauy, *Jour. de Min.* No. xxx. 415.

† Hauy and Descotils, *Jour. de Min.* No. xxx. 415.

‡ Jameson, ii. 597.

a tendency to thin columnar distinct concretions. Transparency 2. Specific gravity 3·315[*].

Sp. 8. *Axinite*[†].

Yanolite of Lametherie—*Axinite* of Hauy—
Thummerstone of the Germans.

This stone was first described by Mr Schreber, who found it near Balme d'Auris in Dauphiné, and gave it the name of *shorl violé*[‡]. It was afterwards found near Thum in Saxony, in consequence of which Werner called it *thummerstone*.

It is sometimes massive; but more commonly crystallized. 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 variety 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.

Common colour clove brown; it passes on the one hand to plum blue, on the other to pearl and ash-grey, and greyish black. External lustre 4; internal 2, 3, vitreous. Fracture fine-grained uneven. Fragments sharp-edged. Massive varieties occur in curved lamellar distinct concretions. Transparency from 4 to 2. Hard; yields to the file. Frangibility 6. Specific gravity from 3·213 to 3·300[¶]. Before the blow-pipe

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[*] Klaproth, Gehlen's *Jour.* Second Series, i. 195.

[†] Kirwan, i. 273.—Pelletier, *Jour. de Phys.* xxvi. 66.—Brochant, i. 236.—Hauy, iii. 22.—Jameson, i. 131.

[‡] Romé de Lisle, ii. 353.

[§] Hauy, *Jour. de Min.* No. xxviii. 264.

[‖] Romé de Lisle, ii. 353.

[¶] Hauy.

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 *.

The following Table exhibits the constituents of the different minerals arranged under the schorl family, according to the most accurate analyses hitherto made:

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* Vauquelin, *Jour. de Min.* No. xxiii. 1.

Schorl. Family.

	Euclase.	Emerald.		Beryl.		Schorlite.	Schorl	Tourmaline.			Pistasite.		Axinite.		Zoisite.			
	*	†	‡	§	‖	¶	**	††	§§	§§	‖‖	¶¶	***	†‡†	†‡‡	‡‡‡	§§§	‖‖‖
Silica - - -	36	64·5	68·50	68	66·45	34	38	40	42	45	37	37	52·7	44	45	47·5	40·25	37·0
Alumina - -	23	16	15·75	15	16·75	48	20	39	40	30	27	21	25·6	18	29	29·5	30·25	26·6
Glucina - -	15	13	12·56	14	15·50													
Lime - - - -		1·6	0·25	2			20	3·84			4	15	9·4	19	21	17·5	22·50	20
Chrom. ox-		3·25	0·30															
Iron oxide	5		1 00	1	0·60	1	19	12·5			17	24	9·6	14	3	4·5	4·5	13
Mang. ox.								2	7	13	1·5	1·5		4				0·6
Fluor. acid						17												
Soda - - - -									10	10								
Moisture -		2·00														·75	2	1·8
Loss - - - -	21		1·70		0·70		3	2·66	1	2	3·5	1·5	2·7	1	2	·25	0·5	1
	100	100·35	100	100	100	100	100	100	100	00	100	00	100	100	100	100	100	100

* Vauquelin, *Jour. de Phys.* lii. 317. † Vauquelin, *Jour. de Min.* No. xxxviii. 98. ‡ Klaproth, *Beitrage*, iii. 226.
§ Vauquelin, *Jour. de Min.* No. xliii. 563. § Klaproth, *Beitrage*, iii. 219. ¶ Bucholz, Gehlen's *Jour.* ii. 38.
** Gerhard, Jameson's *Min.* i. 128. †† Vauquelin, Hauy, iii. 33. A Green tourmaline from Brazil.
§§ Vauquelin, Gehlen's *Jour.* v. 489. Red tourmaline from Siberia; the first transparent, the second blackish
‖‖ Descotils, *Jour. de Min.* No. xxx. 420. ¶¶ Vauquelin, Hauy, iii. 104. *** Klaproth, *Beitrage*, ii. 126.
†‡† Vauquelin, *Jour. de Min.* No. xxiii. 1. ‡‡‡ Klaproth, Gehlen's *Jour.* Second Series, i. 197.
‡‡‡ Bucholz, Ibid. p. 201. ‖‖‖ Laugier, *Phil. Mag.* xxx. 214.

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VIII. QUARTZ FAMILY.

This family is more numerous than any of the preceding, as it contains fourteen species, several of which, on account of the numerous varieties which they present, are farther subdivided into subspecies. The names of the species are *quartz*, *iron flint*, *horn stone*, *flint slate*, *flint*, *chalc dony*, *hyalite*, *opal*, *menilite*, *jasper*, *heliotrope*, *chrysoprase*, *plasma*, *cat's eye*. Many of them are of importance; yet as they never occur crystallized, the method of discriminating minerals adopted by Hauy fails when applied to them.

Sp. 1. *Quartz* [*].

This is one of the most abundant of all the mineral species, occurring in great quantities in almost every situation. It occurs massive, in rolled pieces, and crystallized. The primitive form of its crystals, according to Mr Hauy, is a rhomboidal parallelopiped; the angles of whose rhombs are 94° and 86°; so that it does not differ much from a cube [†]. The most common variety is a dodecahedron, composed of two six-sided pyramids, applied base to base, whose sides are isosceles triangles, having the angle at the vertex 40°, and each of the angles at the base 70°; the inclination of a side of one pyramid to the contiguous side of the other pyramid is 104°. There is often a six-sided prism interposed between the two pyramids, the sides of which al-

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[*] Kirwan, i. 241.—Hauy, ii. 406.—Brochant, i. 239.—Jameson, i. 136.

[†] *Jour. de Min.* No. xxviii. 255.

Quartz. Family.

ways correspond with those of the pyramids [*]. For a description and figure of the other varieties of quartz crystals, and for a demonstration of the law which they have followed in crystallizing, we refer the reader to *Romé de Lisle* [†] and *Mr Haüy* [‡].

Fracture conchoidal or splintery. Its lustre varies from 3 to 1, and its transparency from 4 to 1; and in some cases it is opaque. It causes a double refraction. Hardness from 10 to 11. Specific gravity from 2·64 to 2·67, and in one variety 2·691. To facilitate the description of this complicated species, Werner has subdivided it into five subspecies; a subdivision attended with several advantages.

Subspecies 1. *Amethyst.*

It occurs massive and in rolled pieces, but most frequently crystallized. The crystals are six-sided pyramids, always in druses. Colour violet blue; passing on the one hand to plum blue, clove brown, brownish black; on the other, to pearl and ash grey, greyish white, greenish white, olive green, and, in some rare cases, pistachio green. In the massive varieties several colours appear together in stripes. External lustre 4; internal from 4 to 3, vitreous. Fracture perfect conchoidal; sometimes passes into imperfect conchoidal uneven, and coarse splintery. Fragments sharp-edged. The massive varieties composed of thick prismatic distinct concretions, often shooting into crystals at their extremities. Transparency from 4 to 2. Brittle. Fran-

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[*] *Chrystallog.* ii. 71.

[†] Ibid.

[‡] *Mém. Par.* 1786, p. 78; and *Mineralogie*, ii. 407. See also Lametherie, *Jour. de Phys.* xlii. 470.

gibility 4. Specific gravity 2·750. Found in veins and in the hollow cavities of agates.

Werner distinguishes the common amethyst, above described, from a variety which, from its fracture, he calls *thick fibrous* amethyst. This last occurs only massive and in rolled pieces. Internal lustre 2 to 3, vitreous. Principal fracture thick, fibrous; cross fracture imperfect conchoidal. Transparency usually 2.

Subspecies 2. *Rock Crystal.*

It occurs in rolled pieces, and very often crystallized in all the variety of form belonging to the species in general. Most common colours white and brown. From snow white passes into greyish, yellowish, and reddish white; from greyish white to pearl grey; from yellowish white to ochre yellow, wine yellow, yellowish brown, clove brown, brownish black; from yellowish brown to orange yellow and hyacinth red.

External lustre of the crystals 4, of the rolled pieces 2; internal lustre 4, vitreous. Fracture perfect conchoidal, sometimes flat conchoidal; and in some varities a concealed foliated fracture may be recognized. Fragments very sharp-edged. Occurs very rarely in granular and prismatic distinct concretions. Transparency 4. Frangibility 4. Specific gravity from 2·605 to 2·888.

Subspecies 3. *Milk Quartz.*

Occurs only massive. Colour sometimes milk white; more commonly rose red. The rose red sometimes passes into crimson red, reddish white, pearl grey, and milk white. Internal lustre 3, 4, vitreous, inclining to resinous. Fracture perfect conchoidal. Fragments sharp-edged. Sometimes appears composed of thick lamellar distinct concretions. Transparency 3. Constitutes beds in primitive mountains.

Subspecies 4. Common Quartz.

Occurs massive, in grains, and rolled pieces; in various particular shapes, and crystallized. Colour various shades of white, grey, brown, yellow, green, and red. External lustre of the crystals 4, 3; of the rolled pieces 1, 0; internal lustre 3, vitreous. Fracture coarse and fine splintery, and imperfect conchoidal. Some specimens show a parallel fibrous fracture. Fragments pretty sharp-edged. Sometimes in prismatic, and also in granular distinct concretions. Transparency 2, rarely 3. Frangibility 3. Specific gravity 2·6404 to 2·6546.

Subspecies 5. Prase.

Usually massive; sometimes crystallized. Colour leek green. Lustre 3, 2; between resinous and vitreous. Fracture coarse splintery. Fragments sharp-edged. When massive it is composed of cuneiform, thick, prismatic, distinct concretions. Surface of the concretions rough and transversely streaked. Transparency 2. Hard. Frangibility 2.

This subspecies is considered as consisting of an intimate mixture of quartz and actinolite.

Sp. 2. Iron-Flint *.

This mineral occurs in veins of iron-stone, and is supposed to be an intimate mixture of quartz and iron-ochre.

Commonly massive; sometimes crystallized in small

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* Jameson. i. 134.

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six-sided prisms, acuminated at each extremity by three planes. Colour yellowish brown; sometimes between blood red and brownish red. External lustre 4; internal 3; nearly vitreous. Fracture imperfect small conchoidal. Fragments not very sharp-edged. In small grained distinct concretions. Transparency 0, 1. Hard. Frangibility 2.

Sp. 3. *Hornstone**.—*Chert.*

This mineral occurs sometimes massive, sometimes in round balls. Fracture splintery and conchoidal. Lustre 0, 1. Transparency 1. to 2. Hardness 7 to 9. Specific gravity 2·699 to 2·708. Colour usually grey.

Werner subdivides this species into three subspecies, distinguished chiefly by the fracture and texture.

Subspecies 1. *Splintery Hornstone.*

This mineral is found in veins in limestone, and forms also the basis of a rock called *hornstone porphyry.*

Colour bluish grey, greenish grey, yellowish grey, smoke and pearl grey; flesh red, brownish red; mountain and olive green. Fracture fine splintery. Internal lustre 0, sometimes 1. Fragments sharp-edged. Sometimes, though seldom, it occurs in distinct concretions, which are lameller and concentric. Transparency 1. Hard. Brittle. Frangibility 1. Infusible without addition before the blow-pipe.

Subspecies 2. *Conchoidal Hornstone.*

This mineral occurs in beds, and also in veins. Colour greyish and yellowish white, greenish and pearl

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* Kirwan's *Min.* i. 303.—Baumer, *Jour. de Phys.* ii. 154. and Monnet, Ibid. 33.—Wiegleb, Grell's *Annals*, 1788, p. 46. and 135.—*Jour. de Phys.* liii. 239.—Brochant, i. 25.—Jameson, i. 161.

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grey, flesh and cherry red, mountain green. Sometimes spotted and striped. Always massive. Internal lustre scarcely 2. Fracture perfect conchoidal. Fragments pretty sharp-edged. Never in distinct concretions. Transparency 1. Hard. Frangibility 4.

Subspecies 3. *Woodstone.*

This mineral is found insulated in sandy loam; it appears to be wood converted into hornstone by petrefaction. Colour ash grey, yellowish grey, pearl grey; flesh red, blood red, brownish red; ochre yellow. Usually several colours appear together. Shape conformable to its former woody state. External surface rough. Internal lustre 0, 1. Cross fracture imperfect conchoidal; longitudinal splintery and fibrous. Fragments not sharp-edged. Transparency 1. Rather softer than splintery hornstone. Frangibility 4.

Sp. 4. *Flint-Slate* *.

This mineral occurs in beds and amorphous masses, chiefly in the transition mountains. Colour various shades of grey. Structure slaty. Usually opaque. Transparency sometimes 1. Hardness 9 to 10. Brittle. Specific gravity from 2·880 to 2·415. Infusible *per se*. This species is divided into two subspecies.

Subspecies 1. *Common Flint-Slate.*

Colour ash grey, bluish grey, pearl grey, and cherry red, approaching blood red. Often spotted. Often traversed by veins of quartz. Internal lustre scarcely 1. Fracture, when considered with respect to a considerable mass, or *in the great* as it is termed, *slaty*; *in*

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* Kirwan, i. 305.—Brochant, i. 282.—Jameson, i. 194.

the small, between splintery and uneven. Fragments sharp-edged. Sometimes occurs in lamellar distinct concretions. Transparency 2. Hard. Brittle. Frangibility 2.

Subspecies 2. Lydian Stone.

Colour greyish black passing into velvet black. Massive, and in trapezoidal rolled pieces. Often traversed by quartz veins. External surface smooth. Lustre 2; internal lustre 1. Fracture even. Fragments sharp-edged; sometimes approach the cubical form. Opaque. Hard. Frangibility 4.

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*.

Sp. 5. Flint†.

Pyromachus—Pierre à fusil.

This mineral, 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.

Colour grey, of various shades; namely, *ash, yellowish* and *smoke grey; greyish black; ochre yellow; yellow-*

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* Hill's *Theophrastus*; περι λιθων, p. 190.

† Kirwan's *Min.* i. 301.—Brochant, i. 263.—Hauy, ii. 427.—Jameson, i. 169.—Dolomieu, *Jour. de Min.* No. xxxiii. 693. and Salivet, Ibid. 713. These last gentlemen give an account of the method of making gun flints.

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ish brown, reddish brown; sometimes it approaches *blood red.* Sometimes striped. Occurs massive, in grains and plates, and in various particular shapes. Internal lustre 1. Fracture perfect conchoidal. Fragments very sharp-edged; sometimes tabular. Sometimes, though rarely, it occurs in lamellar distinct concretions. Transparency 2, 1. Rather harder than quartz. Frangibility 4. Specific gravity 2·58 to 2·63. Infusible before the blow-pipe.

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 left hand, or merely supports it on his knee *.

Sp. 6. *Chalcedony* †.

This mineral is found abundantly in many countries, particularly in Iceland and the Faro islands. It is most commonly amorphous, stalactical, or in rounded masses; but it occurs also in pseudo crystals. Surface rough. Fracture even or conchoidal. Lustre external 1; internal 2, 0. Somewhat transparent. Hardness

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* *Jour. de Min.* No. xxxiii. 702.

† Brochant, i. 268.—Kirwan, i. 298.—Hauy, ii. 425.—Jameson, i. 174

10 to 11. Specific gravity 2·615 to 2·700. Brittle. Infusible before the blow-pipe without addition.

Werner subdivides this species into two subspecies; namely, *common calcedony* and *carnelian*, distinguished chiefly by the fracture and lustre.

Subspecies 1. *Common Calcedony.*

Colour *grey*, of various kinds; namely, *smoke*, *bluish*, *pearl*, *greenish*, and *yellowish grey*: the bluish grey passes into milk white and smalt blue: the greenish grey into a colour between grass and apple green: the yellowish grey into honey, wax, and ochre yellow; yellowish brown and blackish brown: this last, when the mineral is held between the eye and the light, appears blood red. Internal lustre nearly 0. Fracture even, sometimes passing into fine splintery; also into uneven, approaching the flat conchoidal. Fragments sharp-edged. Generally in reniform, lamellar, concentric, distinct concretions. Transparency 3. Rather harder than flint. Brittle. Frangibility 2.

Subspecies 2. *Carnelian.*

Colour blood red; passes into flesh red, reddish white, milk white, yellow, reddish brown. External surface rough and uneven. Lustre 2. Fracture perfect conchoidal. Fragments very sharp-edged. Very seldom in distinct concretions. Transparency 3.

Sp. 7. *Hyalite* *.

This mineral occurs in wacke in reniform masses. At first sight it strikes the eye as not unlike gum. The masses are usually very much cracked. Colour yel-

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* Kirwan i. 296.—Brochant, i. 271.—Jameson, ii. 535.

lowish or greyish white. Lustre 3, vitreous. Fracture small flat conchoidal. Fragments sharp-edged. Transparency 2, passing to 3. Hardness 9. Brittle. Frangibility 5. Specific gravity 2·110 *. Infusible at 150° Wedgewood, but yields to soda *.

Sp. 8. *Opal* †.

This mineral 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 opal is always amorphous. Its fracture is conchoidal. Commonly somewhat transparent. Hardness from 6 to 9. Specific gravity from 1·958 to 2·540. The lowness of its specific gravity, in some cases, is to be ascribed to accidental cavities which the stone contains. These are sometimes filled with drops of water. Some specimens of opal have the property of emitting various coloured rays, with a particular effulgency, when placed between the eye and the light. The opals which possess this 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 to the sun. Werner has divided this species into four subspecies.

Subspecies 1. *Precious Opal.*

This mineral is found in Upper Hungary, and said

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* Kirwan.

† Kirwan's *Min.* i. 289.—Hauy, *Jour. de Hist. Nat.* ii. 9.—Delius, *Jour. de Phys.* xliv. 45.—Brochant, i. 341.—Hauy, ii. 434.—Jameson, i. 245.

to be disseminated in clay porphyry. Occurs massive, in plates, and small veins. Colours milk and yellowish white; but between the eye and the light they pass into pale rose red and wine yellow. Exhibits a beautiful play of colours. Internal lustre 4, vitreous. Fracture perfect conchoidal. Fragments sharp-edged. Transparency 2, sometimes 3. Semihard. Brittle. Frangibility 6. Specific gravity 2·114. Does not melt before the blow-pipe. 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.

Subspecies 2. *Common Opal.*

This mineral occurs in many parts of the world, especially in Iceland, the Faro Isles, Ireland, and Germany. Sometimes it is in veins, sometimes disseminated, and most frequently in porphyry.

Principal colour white of various shades; namely, *greyish*, *greenish*, *yellowish*, and *milk white*: from greenish white it passes into apple green; from yellowish into honey and wax yellow: sometimes intermediate between flesh and tile red. The white varieties, when held between the eye and the light, appear wine yellow. Internal lustre 4; sometimes 3, vitreous. Fracture perfect conchoidal. Fragments sharp-edged. Transparency 3. Semihard. Brittle. Frangibility 5. Specific gravity from 1·958 to 2·144.

Specimens of this variety sometimes occur with rifts: these readily imbibe water, and therefore adhere to the tongue. Some opals gradually become opaque, but recover their transparency when soaked in water by imbibing that fluid. They are then called *hydrophanes*, or *oculi mundi*.

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Subspecies 3. *Semi-Opal.*

This mineral, which has been arranged with pitchstone, is very common in different parts of the world, occurring in angular pieces and veins in porphyry and amygdaloid.

Common colours white and grey; namely, yellowish, greenish, and milk white; yellowish, greenish, and ash grey, and greyish black; leek, apple, and olive green; honey and wax yellow, yellowish brown; chesnut and hair brown. Sometimes several colours appear together in spots and clouds. Colours usually muddy. Occurs massive, and in various particular shapes. Lustre 2. Fracture imperfect large flat conchoidal. Fragments sharp-edged. Harder than common opal. Very brittle. Frangibility 4. Specific gravity 2·540 *. Infusible before the blow-pipe.

Subspecies 4. *Wood-Opal.*

This mineral, which occurs near Schemnitz, and at Telkobanya in Hungary, consists of wood penetrated with opal. It occurs in pieces which have the shape of branches and other parts of trees. Colour greyish and yellowish white; sometimes ochre yellow; from greyish white it passes into ash grey and greyish black. Internal lustre 2. Fracture more or less perfect conchoidal, showing the ligneous texture. Fragments sharp-edged. Transparency 2. Harder than opal. Frangibility 4. Specific gravity 2·600.

Sp. 9. *Menilite* †.

This mineral, which occurs in adhesive slate at Menil

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* Klaproth.

† Klaproth's *Beitrage*, ii. 165.—Jameson, ii. 536.

Montagne near Paris, was first made known to mineralogists in 1790. It is found in tuberose masses, with a smooth ribbed surface, sometimes covered with a white crust. Colour chesnut brown; externally marked with stripes of reddish brown and pearl grey alternating with each other. Internal lustre 2. Cross fracture perfect flat conchoidal; longitudinal coarse splintery. Fragments sharp-edged. In flattened longish granular distinct concretions; the surface of which has no lustre, and is sometimes covered with a white crust. Transparency 1, 2. Scratches glass. Brittle. Frangibility 4. Specific gravity 2·185 *.

Sp. 10. *Jasper* †.

This mineral is an ingredient in the composition of many mountains. It occurs usually in large amorphous masses, constituting beds and veins, sometimes in rounded or angular pieces. Either opaque, or its transparency is 1. Hardness 9 to 10. Specific gravity from 2·3 to 2·7. Its colours are various. When heated it does not decrepitate.

Werner subdivides this species into six subspecies; some of which are again subdivided into different kinds, for the conveniency of description.

Subspecies 1. *Egyptian Jasper*.

This mineral has been hitherto found only in Egypt, and in one or two places in Germany. It occurs in rolled pieces, mostly spherical, with a rough surface. Werner, from its colour, divides it into two kinds.

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* Klaproth.

† Kirwan's *Min.* i. 309.—Borral, *Hist. Natur. de Corse.*—Henkel, *Act. Acad. Nat. Curios.* v. 339.—Brochant, i. 332.—Jameson, i. 229.

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I. *Brown Egyptian Jasper.*—Found in Egypt in a breccia, of which the greater part of that country is composed. Colour chesnut brown; sometimes yellowish brown, cream yellow, and yellowish grey. The central part of this mineral has a yellowish grey colour; the exterior part a yellowish brown and chesnut yellow. The brown colour forms concentric delineations, between which the mineral is spotted with black. External lustre 2, 1; internal 2. Fracture perfect conchoidal. Fragments sharp-edged. Transparency 1. Hard. Frangibility 4. Specific gravity from 2·564 to 2·600. Sometimes passes into flint.

II. *Red Egyptian Jasper.*—Found in a bed of red clay iron-stone in the electorate of Baden. Colour between blood and scarlet red; on the surface often ochre yellow, also smoke and bluish grey; colours form ring-shaped delineations. Internal lustre 2 to 0. Fracture large conchoidal. Fragments sharp-edged. Usually opaque. Hard.

Subspecies 2. Striped Jasper.

This mineral occurs in beds, and even constitutes hills. Always massive. Colours pearl, greenish, and yellowish grey; cream and straw yellow; mountain and leek green, and greenish grey; cherry, brownish, and flesh red; plum blue. Several colours always appear together in stripes. Hence the name of the mineral. Internal lustre 0. Fracture pretty perfect conchoidal, approaching to fine earthy. Fragments pretty sharp-edged. Transparency 1, 0. Pretty hard. Brittle. Frangibility 3.

Subspecies 3. Porcelain Jasper.

This mineral is supposed to have been originally a slate clay, hardened by the combustion of subterraneous coal mines. It occurs in whole beds in situations favourable to this opinion. Usually massive and in angular pieces; frequently rent. Colours smoke, bluish, yellowish, and pearl grey; lilac and lavender blue; brick red; straw and ochre yellow; greyish black and ash grey. Generally of only one colour, but often marked with dots and clouds. Often presents *brick red* vegetable impressions, especially the blue varieties. Internal lustre 1, 2; sometimes 3. Fracture imperfect large flat conchoidal. Fragments sharp-edged. Opaque. Hard. Very brittle.

Subspecies 4. *Common Jasper.*

This mineral, which is very common, occurs in veins in primitive mountains. Most commonly massive. Colours yellowish, liver, and blackish brown; ochre yellow; blood red; rarely scarlet and cochineal red; brownish red; brownish black. Sometimes several colours appear together in the same mineral. Internal lustre 3, 2; between vitreous and resinous. Fracture more or less perfect conchoidal, passing into even and earthy. Fragments more or less sharp edged. Usually opaque. Transparency sometimes 1. Pretty hard. Brittle. Frangibility 4.

Werner gives a variety of this subspecies the name of *earthy common jasper*, from its fracture, which is always earthy. It is softer than the preceding; opaque; and its colour is blood red or brownish red.

Subspecies 5. *Jasper Agate.*

This mineral occurs in agate balls in amygdaloid. Always massive. Colours yellowish white, cream and straw yellow, reddish white, and flesh red. The colours are distributed in rings and stripes. Lustre 0. Fracture small flat conchoidal. Fragments scarcely

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sharp-edged. Transparency usually 0; sometimes 1. pretty hard. Often adheres to the tongue.

Subspecies 6. Opal Jasper.

This mineral occurs in nests in porphyry, in Hungary and Siberia. Massive. Colours scarlet, brick, blood, and brownish red; blackish brown, approaching sometimes to liver brown and ochre yellow. Colours sometimes in spots and veins. Internal lustre 3, approaching 4; between vitreous and resinous. Fracture complete flattish conchoidal. Fragments very sharp-edged. Usually opaque. Transparency sometimes 1. Brittle. Frangibility 4. This subspecies connects jasper with opal.

Sp. 11. *Heliotrope* [*].

This mineral, which is found in various parts of Asia and Europe, nearly in the same situation as chalcedony, is supposed by some to be an intimate combination of chalcedony with *green earth.*

Colour between grass and leek green, often stained or striped olive, yellow, red. Found massive, and in angular pieces. Lustre internal 2, resinous. Fracture imperfect large conchoidal. Transparency 1, sometimes 2. Hardness 9. Specific gravity 2·633. Frangibility 4. Infusible before the blow-pipe.

Sp. 12. *Chrysoprase* [†].

This mineral, which has been hitherto found only near Kosemütz in Silesia, is always amorphous. Frac-

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[*] Kirwan, i. 314.—Brochant, i. 276.—Jameson, i. 187.

[†] Kirwan's *Min.* i.—Lehmann, *Mem. Berlin*, 1755, p. 202.—Klaproth, *Beitrage*, ii. 127.—Brochant, i. 280.—Hauy, ii. 426.—Jameson, i. 191.

ture even, sometimes inclining to the splintery. Scarcely any lustre. Transparency 2 to 3. Scarcely so hard as chalcedony. Specific gravity 2·479. Colour apple green. Frangibility 3. In a heat of 130° Wedgewood it whitens and becomes opaque.

Sp. 13. *Plasma**.

Hitherto this mineral has been found only among the ruins of Rome. Colour between grass and leek green; often marked with yellow dots and white spots. Found in angular fragments; often encrusted with an earthy matter. Internal lustre 2. Fracture perfect flat conchoidal. Fragments very sharp-edged. Transparency 2, sometimes 3. Hardness equal to that of chalcedony. Brittle. Frangibility 2. Rather lighter than heliotrope.

Sp. 14. *Cat's Eye* †.

This mineral 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.

Colours yellowish, greenish, and ash grey: Isabella yellow; yellowish, reddish, and hair brown; mountain and olive green; greyish black. Internal lustre 3, between resinous and vitreous. Fracture small im-

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* Brochant, i. 278.—Jameson, i. 189.

† Kirwan, i. 301.—Brochant, i. 292.—Jameson, i. 200.

Quartz Family.

perfect conchoidal. Fragments more or less sharp-edged. Transparency 2; sometimes 3 and 1. Sometimes presents the appearance of slender white fibres almost opaque, which gives it the appearance called *chatoyant* by jewellers. Hard. Frangibility 4. Specific gravity from 2·625 to 2·660.

Constituents.

SEVERAL of the minerals classed under the quartz family owe their peculiar properties, seemingly, rather to the intimate mixture of foreign bodies with the silica, of which they are principally composed, than to any chemical combination. The following Table exhibits the analyses hitherto made to ascertain the constituents of the different species:

	Amethyst.	Rock Crystal.	Flint.		Chalcedony.		Hyalite.	
	*	†	‡	§	‖	¶	**	††
Silica	97·5	93	98	97	84	96·75	57	92
Alumina	0·25	6	0·25	1	16	0·25	18	
Lime		1	0·5				15	
Iron oxide	0·5		0·25	Trace	Trace	0·5	Trace	
Water			1			2·5		8 ‡‡
Loss	1·75			2			10	
	100	100	100	100	100	100	100	100

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* Rose. † Bergman. ‡ Klaproth, *Beitrage*, i. 46.

§ Vauquelin, *Jour. de Min.* No. xxxiii. 702. ‖ Bergman.

¶ Green chalcedony from Mount Olympus, Klaproth, *Beitrage*, iv. 326.

** Link, Crell's *Annals*, 1790, ii. 232.

†† Bucholz, Gehlen's *Jour.* Second Series, i. 202.

‡‡ Water or alkali.

	Precious Opal.	Common Opal.			Semi-opal.	Menilite.	Porcel. Jasper.	Chrysoprase.	Cat's Eye.	
	*	†	‡	§	‖	¶	**	††	‡‡	
Silica	90	98·75	93·50	92	43·5	85·5	60·75	96·16	95·00	94·50
Alumina		0·10				1	27·25	0·08	1·75	2·00
Lime						0·5		0·83	1·50	1·50
Magnesia							3·00			
Iron oxide		0·10	1	0·25	47	0·5	2·50	0·08	0·25	0·25
Nickel oxide								1·00		
Water	10		5	7·75	7·5	11				
Potash							3·60			
Loss		1·05	0·5		2	1·5	2·90	1·85	1·50	1·75
	100	100	100	100	100	100	100	100	100	100

IX. Pitch-stone Family.

This family comprehends under it four different species; namely *obsidian*, *pitch-stone*, *pearlstone*, and *pumice*.

Sp. 1. *Obsidian* §§.

This mineral occurs in nests in the pearl stone of Hungary. It is common in Iceland, Siberia, the Levant islands, and in South America. Found in angular pieces and roundish grains. Principal colour velvet black; occurs also greyish, brownish, and greenish black; ash and smoke grey; hair and clove brown. Often striped and spotted. Fracture perfect conchoidal.

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* Klaproth, *Beitrage*, ii. 153. † Ibid. p. 158. ‡ Ibid. p. 161.

§ The specimen analysed was a green coloured opal brought by Humboldt from Mexico, and distinguished by the name of *Feuer-opals*. Klaproth, *Beitrage*, iv. 156.

‖ Klaproth, *Beitrage*, ii. 164. ¶ Ibid. p. 169. ** Rose.

†† Klaproth, *Beitrage*, ii. 133. ‡‡ Ibid. i. 94, and 96.

§§ Kirwan, i. 221.—Brochant, i. 288.—Hauy, iv. 494.—Jameson, i. 259.

Pitch-stone Family.

Its internal lustre 4, 3, vitreous. Fragments sharp-edged. Transparency 1, 2. Hardness 10. Frangibility 4. Specific gravity 2·348 to 2·432 [*]. Melts into an opaque grey mass.

Sp. 2. *Pitch-Stone* [†].

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 occurs in beds in porphyry; and in beds and veins in the newest floetz trap. Massive. Colours black, green, brown, red, grey, of various shades. Fracture imperfect flat large conchoidal; sometimes approaches the splintery. Lustre from 3 to 1, between vitreous and resinous. Transparency 2 to 1. Hardness 8 to 10. Brittle. Frangibility 5; it often yields even to the nail of the finger. Specific gravity 2·314 [‡] to 1·645 [§]. Fusible. At 21° Wedgewood swells a little; softened at 31°. The green variety from Arran becomes perfectly white and porous at 70° [‖].

Sp. 3. *Pearl-Stone* [¶].

This mineral, which occurs in Tokay in Hungary, in Kamschatka, and near Sandy Brae in Ireland, was first made known to mineralogists under the name of *volcanic zeolite*. Werner, when he introduced it into the system, gave it the name of *pearl-stone*. It is found

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[*] Humboldt, Gehlen's *Jour.* v. 122.

[†] Kirwan, i. 292.—Brochant, i. 353.—Hauy, iv. 386.—Jameson, i. 260.

[‡] Bumenbach.

[§] Klaproth.

[‖] Jameson, i. 262.

[¶] Jameson, i. 269.—Klaproth, iii. 326.

in beds in porphyry usually vesicular, and the vesicles are round. Usual colour grey; sometimes black and red. The varieties of grey are, smoke, bluish, ash, yellowish, and pearl grey; from ash grey it passes into greyish black; from pearl grey into flesh and brick red, and reddish brown. Lustre 3, pearly. Fracture scarcely discernible; appears to be small imperfect conchoidal. Fragments blunt-edged. Occurs in large, angular-grained distinct concretions; these are composed of small round-grained concretions; and these again of very thin lamellar distinct concretions. Transparency 1. Not brittle. Frangibility 6. Soft. Specific gravity 2·340 [*].

Sp. 4. *Pumice* [†].

This mineral occurs in great abundance in the Lipari Islands; it occurs also on the banks of the Rhine and in Hungary. Usually in vesicular masses. Colours light yellowish grey and smoke grey; sometimes ash grey. Lustre in the principal fracture 2, 3, pearly; in the cross 2, vitreous. Principal fracture parallel curved fibrous; cross fracture uneven, and imperfect conchoidal. Fragments blunt-edged and splintery. Transparency 1. Soft. Very brittle. Frangibility 4. Swims in water.

The following Table exhibits the constituents of the preceding minerals, according to the most accurate analyses hitherto made:

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[*] Klaproth.

[†] Jameson, i. 272.

	Obsidian.				Pitch-stone.	Pearl-stone.		Pumice.
	[*]	[†]	[†]	[‡]	[§]	[‖]	[¶]	[**]
Silica	72·0	72	71	78	73	75·25	77	77·50
Alumina	12·5	14·2	13·4	10	14·5	12·00	13	17·50
Lime		1·2	1·6	1	1·0	0·50		
Iron oxide	2·0	3	4·0	2	1·0	1·60	2	1·75
Mang. ox.				1·6	0·1			
Potash	10	3·3	5	6		4·50	2	3·00
Soda					1·75		0·7	
Water					8·50	4·50	4	
Loss	3·5	6·3	5	1·4	0·15	1·65	1·3	0·25
	100	100	100	100	100	100	100	100

Zeolite Family.

Constituents.

From these analyses, it appears that all the species are composed very nearly of the same ingredients; namely, about six parts of silica, one of alumina, and a portion of fixed alkali.

X. Zeolite Family.

This family contains twelve species; namely, *wavellite*, *prehnite*, *needle-stone*, *zeolite*, *analcime*, *staurolite*, *lomonite*, *dipyre*, *natrolite*, *azurite*, *lazulite*, *siderite*.

Sp. 1. *Wavellite* [‡‡].

Hydrargillite of Davy.

This mineral was found long ago by Dr Wavell, in a quarry near Barnstaple in Devonshire. Dr Babington examined it; and concluding, from its physical cha-

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[*] Descotils, Gehlen's *Jour.* v. 122.

[†] Drappier, Ibid.

[‡] Vauquelin, Ibid. p. 230.

[§] Klaproth, *Beitrage*, iii. 265.

[‖] Ibid. p. 331.

[¶] Vauquelin, Gehlen's *Jour.* v. 230.

[**] Klaproth, *Beitrage*, iii. 265.

[‡‡] Davy, Nicholson's *Jour.* xi. 153.—Gregor, Ibid. xiii. 247.

racters, that it differed from all minerals previously described, gave it the name of *wavellite*, from the discoverer. Mr Davy and Mr Gregor lately subjected it to a chemical analysis.

Of this mineral there are two subspecies, which have been distinguished by Mr Gregor, who had an opportunity of examining various specimens of the mineral from the mine called Stenna Gwyn in the parish of St Stephen's, Cornwall.

Subspecies 1. *Soft Wavellite.*

It consists of an assemblage of minute crystals attached in tufts to quartz, and radiating from the point of adherence. Sometimes they adhere pertinaciously; at others they are easily separated. Size of the crystals various; sometimes they have the appearance of a fine powder or down; the larger sort about the size of a hair. Seldom above a quarter of an inch in length. Seem to consist of four-sided prisms; when broken the section is rhomboidal. Colour white. Surface sometimes stained ochre yellow. Easily reduced to a powder of a brilliant whiteness. Transparent. Specific gravity 2·22. Infusible before the blow-pipe *.

Subspecies 2. *Compact Wavellite.*

It consists of an assemblage of crystals, closely compacted together in the form of mamillary protuberances, of the size of small peas, and intimately connected together. A stratum of these, about ⅛th inch thick, is spread upon quartz in the cavities of granite. Striæ diverge from a centre. Colour the same as the preceding. Hard enough to scratch calcareous spar. Specific gravi-

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* Gregor.

Zeolite Family.

ty 2·253. Does not imbibe water. Decrepitates when suddenly heated[*]. Does not become electrical or phosphorescent by heat or fusion[†].

Sp. 2. Prehnite[‡].

Though this stone had been mentioned by Sage[§], Romé de Lisle[‖], and other mineralogists, Werner was the first who properly distinguished it from other minerals, and made it a distinct species. The specimen which he examined was brought from the Cape of Good Hope by Colonel Prehn; hence the name *prehnite,* by which he distinguished it. It was found near Dunbarton by Mr Grotche[¶]; and since that time it has been observed in other parts of Scotland.

It is both amorphous and crystallized. The crystals are in groups and confused: they seem to be four-sided prisms with dihedral summits[**]. Sometimes they are irregular six-sided plates, and sometimes flat rhomboidal parallelopipeds.

Colour greenish white, greenish grey, mountain green, apple green, yellowish grey, and yellowish green. External lustre 3; internal 3, 2, pearly. Fracture sometimes foliated, with an imperfect single cleavage; sometimes radiated. Fragments wedge-shaped. The foliated varieties are composed of granular distinct concretions; the radiated in wedge-shaped distinct concretions. Transparency 2; sometimes 3, and even 4.

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[*] Gregor.

[†] Davy.

[‡] Kirwan, i. 274.—Hassenfratz, *Jour. de Phys.* xxxii. 81.—Sage, Ibid. xxxiv. 446.—Klaproth, *Beob. der Berlin,* 2 Band. 211; and *Ann. de Chim.* i. 201.—Hauy, iii. 167.—Brochant, i. 295.—Jameson, i. 204.

[§] *Miner.* i. 232.

[‖] *Crystall.* ii. 275.

[¶] *Ann. de Chim.* i. 213.

[**] Hauy, *Jour. de Min.* No. xxviii. 277.

Scratches glass slightly. Frangibility 4. Specific gravity 2·097 to 2·6969 *. Before the blow-pipe froths strongly, and melts into a brown enamel.

The mineral called *koupholite* is supposed to be a variety of foliated zeolite.

Sp. 3. *Needle-Stone* †.

This mineral, which has hitherto been found only in Iceland and in Britanny, seems to have been considered as a variety of zeolite, till Werner lately distinguished it as a separate species.

Common colour yellowish white. Occurs massive, and crystallized in rectangular four-sided acicular prisms, flatly acuminated by four planes set on the lateral faces. Crystals sometimes scopiform aggregated, sometimes intersect each other. They are longitudinally streaked. External lustre 3, bordering on 4; internal 2, vitreous. Principal fracture imperfect narrow straight radiated; cross fracture uneven and glassy. Composed of very thin columnar distinct concretions, again aggregated into large angular concretions. Transparency of the amorphous 2, of the crystals 4. Hard. Brittle.

Sp. 4. *Zeolite* ‡.

This mineral was first noticed by Cronstedt, who described it in the Stockholm Transactions for 1756, and gave it the name which it now bears; but it is to Wer-

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* Hauy.

† Jameson, ii. 599.

‡ Kirwan, i. 278.—Guettard, iv. 637.—Bucquet, *Mem. Sav. Etrang.* ix. 576.—Pelletier, *Jour. de Phys.* xx. 420.—Hauy, iii. 151.—Brochant, i. 298.—Jameson, i. 208.

ner and Hauy that we are indebted for the exact discrimination of its different varieties. Werner subdivides it into four subspecies, distinguished chiefly by their fracture.

Zeolite Family.

Subspecies 1. *Mealy Zeolite.*

This mineral occurs in the same situations as the other subspecies, and is not uncommon. Colour yellowish or reddish white. Occurs massive and coralloidal, and sometimes covers the surface of the other subspecies. Internal lustre 0. Fracture coarse earthy; sometimes delicately fibrous. Fragments blunt-edged. Opaque. Very soft. Frangibility 4. Light. When the finger is drawn across it, a sound is given not unlike that from burnt bricks.

Subspecies 2. *Fibrous Zeolite.*

This mineral, like all the other subspecies, occurs chiefly in rocks belonging to the floetz trap formation. It is massive, in balls, and likewise in capillary crystals. Colours snow white, yellowish white, greenish white, reddish white; ochre yellow; greenish grey; flesh red. Internal lustre 1, 2, pearly. Fracture fine fibrous; sometimes splintery. Fragments wedge-shaped. In granular distinct concretions. Transparency 2. Semihard. Frangibility 4.

Subspecies 3. *Radiated Zeolite.*

Mesotype of Hauy.

This subspecies is found massive, globular, and crystallized. The primitive form of its crystals, according to Hauy, is a rectangular prism, whose bases are squares. The most common variety is a long four-sided prism, terminated by low four-sided pyramids*.

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[*] Hauy, *Jour. de Min.* No. xiv. 86.

Colour yellowish, greyish, reddish, and snow white. External lustre 3, 4, pearly; internal 2, pearly. Fracture narrow and broad radiated. Fragments sometimes wedge-shaped. In large longish distinct concretions. Transparency 2; sometimes 3. Occasions double refraction. Scratches calcareous spar. Brittle. Frangibility 4. Absorbs water. Specific gravity 2·0833. When heated it becomes electric like the tourmaline[*]. Before the blow-pipe it froths[†], emits a phosphorescent light, and melts into a white semitransparent enamel, too soft to cut glass, and soluble in acids. In acids it dissolves slowly and partially without effervescence; and at last, unless the quantity of liquid be too great, it is converted into a jelly.

Subspecies 4. *Foliated Zeolite.*

Stilbite of Hauy.

This mineral occurs massive, globular, and crystallized. The primitive form of its crystals is a rectangular prism, whose bases are rectangles. It crystallizes sometimes in dodecahedrons, consisting of a four-sided prism 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[‡].

Colour yellowish or greyish white; and sometimes, though seldom, snow and reddish white. Internal lustre 3, 4, pearly. Fracture perfect foliated; folia somewhat curved; cleavage single. In granular, and sometimes,

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[*] Hauy, *Jour. de Min.* No. xxviii. 276.

[†] Hence the name *zeolite;* from ζεω and λιθος.

[‡] Hauy, *Jour. de Min.* No. xiv. 86.

though rarely, in lameller distinct concretions. Transparency of the crystals 3, 4; of the massive 2. Hardness inferior to that of radiated zeolite. Brittle. Specific gravity 2·500 *. 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 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 †. Does not gelatinize in acids. Not electric by heat.

Sp. 5. *Analcime* ‡.

Cubizite of Werner.

This stone, which was discovered by Mr Dolomieu, is found crystallized in the cavities of basalt. It was first made a distinct species by Mr Hauy. Mineralogists had formerly confounded it with zeolite.

Crystals.

The primitive form of its crystals is a cube. It is sometimes found crystallized in cubes, whose solid angles are wanting, and three small triangular faces in place of each; sometimes in polyhedrons with twenty-four faces. External lustre 4, between pearly and vitreous: internal 3. Fracture very imperfect foliated. Cleavage triple, parallel to the sides of the cube. Fragments approaching to cubic. Has a tendency to granular distinct concretions. Transparency

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* Hauy, *Jour. de Min.* No. xxviii. 276.

† Vauquelin, Ibid. No. xxxix. 161.

‡ Hauy, iii. 180.—Brochant, i. 309.—Jameson, i. 218.

from 2 to 3. Hardness about 9; scratches glass slightly. Specific gravity above 2. Colour white; sometimes red. 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 †.

Sp. 6. *Chabasie* ‡.

This mineral, which was first separated from the preceding species by Bosc d'Antic and Hauy, is found at Oberstein in Germany. It is found usually in crystals. The primitive form is a rhomboid differing very little from a cube, having the angle at its summit 93½°. Sometimes it occurs in that form; at other times six of its edges are truncated, and the truncatures unite, three and three, at the two opposite angles, while the other six angles are truncated: sometimes in double six-sided pyramids applied base to base, having the six angles at the base and the three acute edges of each pyramid truncated. Colour white; sometimes transparent. Specific gravity 2·7176. Scratches glass. Melts before the blow-pipe into a white spongy mass.

Sp. 7. *Staurolite* §.

Andreolite of Lametherie—*Hyacinthe blanche cruciforme*, var. 9. of Romé de Lisle—*Harmotome* of Hauy.

This stone has been found at Andreasberg in the

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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.

‡ Hauy, iii. 176—Brochant, i. 309.

§ Kirwan, i. 282.—Hauy, iii. 191.—Brochant, i. 311.—Jameson, i. 222.—See also Gillot, *Jour. de Phys*. 1793, p. 1, and 2.

Hartz, and at Strontian in Argyleshire in veins. At Oberstein it occurs crystallized in agate balls. 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. Sometimes these prisms occur solitary. Primitive form an octahedron with isosceles triangular faces. The faces of the crystals striated longitudinally.

Colour greyish white. Lustre 3, between pearly and vitreous. Cross fracture uneven, sometimes small conchoidal; longitudinal fracture foliated. Transparency 2, 3. Scratches glass easily. Frangibility 4. Specific gravity 2·333 to 2·361. When heated slowly, it loses 0·15 or 0·16 parts of its weight, and falls into powder. It effervesces with borax and microcosmic salt, and is reduced to a greenish opaque mass. With soda it melts into a frothy white enamel. When its powder is thrown on a hot coal, it emits a greenish yellow light *.

Sp. 8. *Lomonite* †.

This mineral was named by Werner from Gillet Laumont, who found it in 1785 in the mine of Huelgoët. Colour snow white. Massive. Fracture foliated; surface of the folia streaked, which gives a peculiar lustre to the surface of the mineral. Lustre 3, pearly. Composed of longish granular distinct concre-

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* Hauy, *Jour. de Min.* No. xxviii. 280.

† Jameson, ii. 540.—Hauy, iv. 410.

tions. Transparency scarcely 2. Very soft. Sectile. Frangibility 4. Rather light.

According to Hauy, it yields a six-sided prism by mechanical division, still farther divisible in the direction of the diagonals. The mineral, while kept from the external air, preserves a certain degree of cohesion; but when exposed it soon splits in the direction of the folia, and falls into small pieces.

Sp. 9. *Dipyre* *.

Schmelzstein of Werner.

This mineral has been found at Mauleon in the Pyrenees, imbedded either in fascicular masses or in small prisms in a rock of steatite. Colour reddish or greyish white. Longitudinal fracture foliated, and the folia are parallel to the plains of the regular hexahedron. Lustre 3, glassy. Hardness 8. Frangibility 4. Specific gravity 2·630. Melts and froths before the blow-pipe. Phosphoresces slightly on hot coals.

Sp. 10. *Natrolite* †.

This mineral, which was first described and analysed by Klaproth, received its name from that illustrious chemist, on account of the large proportion of soda which it contains. Hitherto it has been found only in the mountains of Suabia, where it borders on Switzerland.

Colours yellowish white, cream yellow, and light

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* Brochant, ii. 508.—Hauy, iii, 242.—Jameson, ii. 562.

† Jameson, ii. 54 .

yellowish brown. These colours form stripes, which are curved in the direction of the external surface. Massive and reniform. Surface drusy, being covered with minute crystals, seemingly rhomboidal. Internal lustre 1. Fracture delicate fibrous. Occurs in granular distinct concretions. Harder than staurolite. Transparency 1. Frangibility 4. Before the blow-pipe it melts easily into a transparent glass full of cavities.

Sp. 11. *Azurite*[*].

Lazulite of Werner.

This mineral was first made known to mineralogists by Klaproth[†], who gave a short description of it as found at Vorau in Austria, and proved that it differed from every other known mineral. A substance, to which the same name was given, was found afterwards in Stiria near Waldbach, and in the neighbourhood of Wienerisch Neustadt; and described and analysed in 1806 by Bernhardi and Trommsdorff[‡]. A mineral was discovered about the same time by Baron Von Moll, to which the name of *mollite* was first given. It was afterwards called *siderite*; and Mohs showed that it was the same with the azurite. In 1807 Leonhard[§] published a description of the *lazulite* and *siderite*, which he considers as two distinct species. According to him, Bernhardi, Trommsdorff, and Mohs had seen only the lazulite and not the siderite. Leonard's description of the lazulite differs considerably from that of Bernhardi.

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[*] Jameson's *Min.* ii. 542.

[†] *Beitrage*, i. 197.

[‡] Gehlen's *Jour.* Second Series, i. 204.

[§] Ibid. iii. 101.

Book III. Chap. II.

In 1807, Klaproth[*] published a description and analysis of a mineral from Krieglach in Stiria, which he called *lazulite*, but which obviously differed in its properties both from the *lazulite* and *siderite* of preceding writers.

From the preceding account, it is obvious that there is a good deal of confusion in the mineralogical description of the *azurite*. The present state of Europe preventing specimens from these countries coming to Britain, it is hazardous to venture to give an opinion, without having an opportunity of examining the minerals themselves. It can scarcely be doubted, however, that at least two species, or more probably three, have been confounded together under the same name. The name *azurite* is here confined to the mineral originally pointed out by Klaproth as from Vorau.

It occurs imbedded in mica slate, and according to Leonhard in the rifts of clay-slate. Colour intermediate between berlin and smalt blue. Disseminated and in crystals, which are imperfect, but appear to be four sided prisms[†]. The sides of the prisms are sometimes smooth, sometimes faintly streaked longitudinally. Lustre 2, 3, vitreous. Fracture large grained uneven, passing into imperfect foliated. Fragments indeterminate, pretty blunt edged. Transparency scarcely 1. Semihard. Brittle. Frangibility 4.

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[*] *Beitrage*, iv. 279.

[†] Bernhardi describes the crystals as octahedrons; but Leonhard says he never perceived any such figure in the azurate of Saltzburg.

Zeolite Family.

Sp. 12. *Siderite*[*].

This mineral has hitherto been found only in a gypsum mountain in Salzburg. Colour intermediate between berlin and indigo blue, mixed with a little grey. It occurs disseminated, and never crystallized. External lustre accidental, internal 3, vitreous, approaching the resinous. Fracture perfect small conchoidal. Fragments tabular, not remarkably sharp-edged. In small angular granular concretions. Transparency 1. Hard, gives sparks with steel. Brittle. Frangibility 2.

Sp. 13. *Lazulite*[†].

Lapis Lazuli of Mineralogists.

This stone, which is found chiefly in the northern parts of Asia, was long known to mineralogists by the name of *lapis lazuli*.

Colour azure blue. Some varieties pass into berlin blue, and others into smalt blue. Found massive, disseminated, and in rolled pieces. Lustre 2, 1. Fracture fine-grained uneven. Transparency 1. Scratches glass. Brittle. Frangibility 4. Specific gravity 2·76 to 2·945[‡].

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

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[*] Leonhard, Gehlen's *Jour.* Second Series, iii. 102.

[†] Kirwan, i. 283.—Hauy, iii. 145.—Brochant, i. 313.—Jameson, i. 225.

[‡] Brisson.

Book III. Chap. II.

published an analysis of lazulite in the Berlin Memoirs for 1758. His analysis has since been confirmed by Klaproth. Lermina has lately announced that this mineral has been found crystallized in garnet dodecahedrons *.

SUCH are the characters of the numerous species belonging to the zeolite family. The following Table exhibits their constituents, as far as they have hitherto been ascertained by chemical analysis :

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* *Ann. de Chim.* l. 144.

Zeolite Family.

	Wavelite.		Prehnite.		Mealy Zeolite.	Fibrous Zeolite.	Radiated Zeolite.	Foliated Zeolite.	Analcime.	Staurolite.	Dipyre.	Natrolite.	Azurite.	Lazulite.
	*	†	‡	§	‖	¶	**	††	‡‡	§§	‖‖	*,*	†‡†	‡‡‡
Silica		6·12	43·8	50·0	50	41	53·00	52·0	43·33	49	60	48·00	10	46·0
Alumina	70	58·70	30·33	20·4	20	31	27·00	7·5	22·66	16	24	24·25	66	14·5
Lime	1·4	0·37	18·33	23·3	8	11	9·46	9·0	3·34		10		2	28
Magnesia				0·5									18	
Barytes										18				
Oxide of iron		0·19	5·66	4·9				—				1·75	2·5	3·0
Soda									9·34			16·50		
Sulph. of lime														6·5
Water	26·2	30·75	1·16	0·9	22	15	10·00	18·5	21	15	2	9·00		2·0
Loss	2·4	3·87	0·96			2	0·54	3·0	0·33	2	4	0·50	1·5	
	100	100	100	100	100	100	100	100	1 0	100	100	100	100	100

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* Davy, Nicholson's *Jour.* xi. 157. Mr Davy has since found that the mineral contains a portion of fluoric acid in a particular state. † Gregor, Ibid. xiii. 254. ‡ Klaproth, *Ann. de Chim.* i. 208. § Hassenfratz, Ibid. and *Jour. de Phys.* xxxiii. 81. ‖ Pelletier, Jameson's, *Miner.* i. 210. ¶ Meyer, Ibid. p. 212. ** Vauquelin, *Jour. de Min.* No. xliv. 576. †† Vauquelin, Ibid. No. xxxix. 164. ‡‡ Vauquelin, *Ann. du Mus. D'Hist. Nat.* ix. 333. The soda was mixed with some potash. §§ Klaproth, *Beitrage*, ii. 83. ‖‖ Vauquelin, Hauy's *Miner.* iii. 243. *,* Klaproth, Jameson's *Min.* ii. 542. †‡† Klaproth found this mineral to contain silica, alumina, and oxide of iron; but the small quantity analysed, prevented him from ascertaining the proportion of the constituents. *Beitrage*, i. 197. The analysis given in the Table is by Trommsdorff. Gehlen's *Jour.* Second Series, i. 208. ‡‡‡ Klaproth, *Beitrage*, i. 196. The lime was in the state of carbonate.

From the preceding Table, it appears that all the species resemble each other very closely in their composition. They all consist of silica and alumina, united to an alkaline substance, and a considerable proportion of water. This alkaline substance is usually lime; but in staurolite it is barytes, and in natrolite soda. Wavellite differs from the rest in being destitute of the alkaline ingredient, and in containing a very small proportion of silica.

XI. FELSPAR FAMILY.

THIS family consists of six species, most of which have been but lately admitted into the mineral system. These are *andaluzite*, *felspar*, *scapolite*, *wernerite*, *spodumene*, *ichthyophthalmite*.

Sp. 1. *Andaluzite* *.

This mineral was discovered by Bournon in a primitive granitic mountain in Forez, and described by him in the Journal de Physique of 1789. At first it was considered as a variety of corundum or felspar. It has been found in Aberdeenshire in Scotland.

Colour flesh red, sometimes approaching to rose red. Massive, and crystallized in rectangular four-sided prisms. Fracture imperfect foliated. Transparency 2. Scratches quartz, and even sometimes spinell. Frangibility 4. Specific gravity 3·165. Infusible by the blow-pipe without addition.

Sp. 2. *Felspar* †.

This is one of the most widely distributed and most abundant of minerals, forming a constituent of granite,

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* Kirwan, i. 337.—Hauy, iv. 362.—Jameson, ii. 544.

† Kirwan, i. 316.—Hauy, ii. 590.—Brochant, i. 361.—Jameson, i. 275.

Felspar Family.

gneiss, and many other primitive and transition rocks. It is very frequently crystallized, and the primitive form of its crystals is an irregular parallelopiped. Occurs usually in rhomboidal prisms, or in six or ten sided prisms, terminated by irregular summits. It gives out a peculiar odour when rubbed. Becomes electric by friction, but with great difficulty. Fusible *per se* into a more or less transparent glass. When crystallized it decrepitates before the blow-pipe. For the conveniency of description, Werner divides this species into five subspecies.

Subspecies 1. *Adularia.* This subspecies was first observed by Mr Pini on the summit of Mount St Gothard, in Switzerland, called Adula; hence its name. It has been found also in other places. The variety called *moonstone* comes from Ceylon.

Colour greenish white, often inclining to asparagus green. Sometimes has milk-white spots, with a silvery lustre. Found massive, in rolled pieces, and crystallized in oblique four-sided prisms, bevelled on both ends; in six sided prisms; and in rectangular four-sided prisms, with oblique terminal faces. Crystals streaked longitudinally. External lustre 4, pearly: lustre of the principal fracture 4; of the cross fracture 3, between vitreous and pearly. Principal fracture perfect specular splendent, with a double rectangular cleavage; cross fracture small imperfect conchoidal. Fragments rhomboidal. Tends to thick straight lamellar distinct concretions. Transparency 3, 2. Hardness 9 to 10. Brittle. Frangibility 4. Specific gravity 2·559.

Subspecies 2. *Labradore Felspar.* This subspecies was first observed on the coast of Labradore by Mr Wolfe,

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and since that time it has been discovered in the northern parts of the old continent.

Colour smoke grey, which passes into dark ash and yellowish grey; in certain positions it reflects a great variety of colours, as blue, green, yellow, red, brown. Occurs commonly massive and in rolled pieces. Fracture perfect foliated, folia crossing at right angles. Lustre of the principal fracture 3, 4; of the cross fracture 2, between pearly and vitreous. Usually in granular distinct concretions; sometimes in thick straight lamellar distinct concretions. Transparency 2. Specific gravity 2·67 to 2·69.

Subspecies 3. *Common Felspar.* Colours white, red, grey, and green. The varieties of grey are smoke and bluish grey; of white, greyish, milk, yellowish, greenish, and reddish white; of red, flesh, blood, and brick red; of green, asparagus, leek, mountain, and verdegris green. Occurs massive, in rolled pieces, and in grains; also crystallized in six and four sided prisms. External lustre 3: lustre of the principal fracture 3, 4; of the cross fracture 1, vitreous. Fracture more or less perfect foliated; cleavage double, the folia intersecting at right angles; cross fracture fine-grained uneven, passing into splintery. Occurs in granular distinct concretions. Transparency 2. Scratches glass. Brittle. Frangibility 4. Specific gravity from 2·4378 to 2·594*.

This subspecies frequently occurs in a *disintegrated* state, and then approaches porcelain clay; except that the crystalline form may sometimes be recognised. Its colour is yellowish or reddish white, sometimes ver-

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* Hauy.

Felspar Family.

ging on grey. Internal lustre between 2 and 0. Fracture sometimes imperfect foliated, passing into earthy; sometimes between uneven and earthy. Usually opaque. Soft. Frangibility 4.

Subspecies 4. *Hollow Spar. Chiastolite* of Karsten —*Macle* of Hauy and Romé de Lisle. This singular mineral was first observed in Britanny, and near St Jacques de Compostella in Spain. It is always crystallized in four-sided prisms nearly rectangular. When we view the end of the prism, we perceive in the centre of it a blackish prism inclosed in the larger one, which is of a greyish, yellowish, or reddish white colour. From each angle of the central prism, a blackish line passes to the corresponding angle of the outer prism; and in each of these external angles there is commonly a small prismatic space, filled with the same matter as that of which the central prism is composed. This matter is a blackish coloured clay slate, the same as the rock in which the hollow spar is found imbedded.

Fracture foliated. Cleavage double, the folia being parallel to the lateral planes of the prism. Transparency 2, but 0 when the crystals are in the state of decomposition. Scratches glass when in a fresh state. Specific gravity 2·9444. When rubbed upon sealing wax, it usually communicates negative electricity *. Before the blow-pipe it is converted into a whitish scoria. The clay slate yields a black glass.

Subspecies 5. *Compact Felspar. Petrosilex* of the older French mineralogists. This mineral occurs abundantly in many countries, being a constituent of green-

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* Hauy, iii. 268.—Jameson, ii. 545.

stone. Colours grey, white, blue, green, and red. The varieties of grey are greenish, smoke, and ash grey ; of green, apple, pistachio, mountain green ; of blue, sky and smalt blue ; of red, flesh and blood red. Occurs massive, in rolled pieces, and in crystals, in antique green porphyry. Internal lustre 2, 1. Fracture appears splintery, but on examination proves to be very small foliated. Sometimes in fine granular distinct concretions. Transparency 2, 1. Hardness 9. Frangibility 4. Melts before the blow-pipe without addition *.

Sp. 3. *Meionite* †.

White Hyacinth of Somma of Romé de Lisle.

This mineral is found on Somma among the sub-

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* From the description and analysis of Klaproth (*Beitrage*, iv. 279.), it appears, that the mineral, formerly considered as the blue variety of compact felspar, is in reality a distinct species. It occurs in a mountain in Stiria, where it performs the part of felspar ; the rock being composed chiefly of quartz and mica. Its colour is azure blue, passing into bluish white. Internal lustre 2, resinous. Fracture splintery, passing into concealed foliated. Fragments indeterminate, not sharp-edged. Transparency 1. Streak snow white. Semihard. Specific gravity 3·046. Before the blow-pipe it becomes isabella-yellow, and splits, but does not melt. With phosphate of soda or borax it gradually melts into a transparent glass bead. Its constituents are

Alumina -	71
Silica - -	14
Magnesia -	5
Lime - -	3
Iron oxide -	0·75
Potash - -	0·25
Water - -	5
Loss - - -	1
	100

† Hauy, ii. 586. Tonnelier, Nicholson's *Jour.* xxi. 191.

stances ejected by Mount Vesuvius. It was first described by Romé de Lisle, and constituted into a peculiar species by Hauy. Werner has not yet admitted it into his system, suspecting it to be only a variety of felspar, to which it bears a certain resemblance; but the shape of its crystals is incompatible with that supposition.

The meionite occurs most usually in crystals, though sometimes it is observed in irregular grains. The primitive form of its crystals is a rectangular prism whose bases are squares. It occurs most commonly in an eight sided prism terminated by four sided pyramids. Sometimes the prism is twelve sided by the truncation of some of its edges. Colour greyish white. Lustre 3, vitreous. Fracture flat conchoidal. Transparency 2. Scratches glass but not felspar. Melts before the blowpipe into a white spongy glass.

Sp. 4. *Scapolite* [*].

Paranthine of Hauy.

This mineral has been hitherto found only near Arendal in Norway, in mines of freestone. Colour greyish, yellowish, and greenish white. Massive; but more commonly crystallized in long, thin, oblique, four-sided prisms, often acicular. Primitive form, a rectangular prism. Crystals slightly streaked longitudinally; aggregated into thick fasciculi, which are again united together. External lustre 2; internal 3, 2, between resinous and pearly. Longitudinal fracture imperfect foliated; cross fracture fine grained uneven. Transpa-

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[*] Brochant, ii. 526.—Hauy, iii. 393.—Jameson, ii. 547.

rency 2. Scratches glass. Brittle. Frangibility 4. Specific gravity from 2·7404 to 3·708. Before the blow-pipe, froths and melts into a white enamel *.

Sp. 5. *Wernerite* †.

Arctizite of Werner.

This mineral was discovered and described by Dandrada, who named it after Werner. Hitherto it has been found only in Sweden and Norway. Colour greenish grey; surface of the crystals between sky blue and celadon green. Massive, and crystallized in low equiangular eight-sided prisms, terminated in flat four-sided pyramids. Internal lustre 2, 3, pearly. Fracture foliated. From the appearance of the folia, Werner gives the fracture the name of *torn*-foliated. Transparency 2. Scratches glass, and strikes fire with steel; but is scratched by felspar. Specific gravity 3·6063. The powder phosphoresces when heated. Before the blow-pipe, froths and melts into an imperfectly white and opaque enamel.

Sp. 6. *Spodumene* ‡.

Triphane of Hauy.

This mineral, which has been found in the mine of Uton in Sweden, and in Norway, was first described by Dandrada. Colour greenish white, sometimes apple green. Massive. Lustre of the principal fracture 3; of the cross fracture 2, pearly. Principal

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* Dandrada.

† Hauy, iii. 119. Brochant, ii. 529.—Jameson, ii. 548.

‡ Hauy, iv. 407.—Brochant, ii. 528.—Jameson, ii. 600.

fracture foliated; cleavage double, the folia intersecting obliquely; cross fracture fine-grained uneven. According to Hauy, it yields by mechanical division a rhomboidal prism, with angles of 100° and 80°. Fragments sometimes in oblique rhombs. The massive varities exhibit granular distinct concretions. Transparency 2. Scratches glass, and strikes fire with steel. Frangibility 6. Specific gravity 3·1923 to 3·218[*]. When heated in a crucible it splits into small plates; many of a golden yellow colour, like some varieties of mica; others are dark grey: in a few days they all lose their lustre, and become dark grey[†]. Melts before the blow-pipe into a greyish globule.

Sp. 7. *Ichthyophthalmite*[‡].

Apophyllite of Hauy.

This mineral is said to occur in Uton, in Sudermania. Colour yellowish, reddish, greyish, and greenish white. Occurs massive, and crystallized in rhomboids which deviate very little from cubes, in rectangular four-sided tables having their edges truncated, and in thick six-sided tables. External lustre of the crystals 4, and they are distinguished by a characteristic lustre; internal 4, 2, pearly. Principle fracture foliated, with a single cleavage parallel to the lateral faces of the table; its lustre 4. Cross fracture fine-grained uneven; its lustre 2. Transparency 3; sometimes 2, 1. Semihard. Frangibility 5. Specific gravity 2·491.

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[*] Hauy and Dandrada.

[†] Vauquelin, Hauy, iv. 408.

[‡] Jameson, ii. 601. Karsten, Gehlen's *Jour.* v. 35.

Before the blow-pipe, froths and melts into an opaque bead [¶].

The following Table exhibits the constituents of the different species belonging to the felspar family, as far as they have been hitherto analysed :

	Adularia.		Labradore.	Common Felspar.			Scapolite.		Spodumene.	Ichthyophthalmite.
	*	†	‡	§	**	**	††	‡‡	§§	‖‖
Silica	64	68·5	69·5	46	62·83	74	48	45	56·5	52·0
Alumina	20	20·5	13·6	24	17·02	14·5	30	33	24·0	
Lime	2	7		6·25	3·00	5·5	14	17·6	5·0	24·5
Soda								1·5		
Potash	14				13·00			0·5		8·1
Oxide of iron		1·5	0·3	2·0	1·00		1	1	5·0	
Water							2			15·0
Sulph. of lime			12·0							
Ox. of copper			0·7							
Loss		2·5	3·9	3·75	3·15	6	5	1·4	9·5	4
	100	100	100	100	100	100	100	100	100	100

[¶] Fourcroy and Vauquelin.

[*] Vauquelin, Hauy, ii. 592. [†] Chenevix, *Phil. Trans.* 1802, p. 337.

[‡] Bindheim, Kirwan's *Mineral* i. 315. But the specimen analysed seems to belong to the common green coloured Siberian felspar, analysed by Vauquelin with a different result.

[§] Chenevix, *Phil. Trans.* 1802, p. 334. [**] Vauquelin, Hauy, ii. 593.

[††] Abilgard, *Jour. de Phys.* lii. 33.

[‡‡] Laugier, *Ann. du Mus. D'Hist. Nat.* x. 472.

[§§] Vauquelin, Hauy, iv. 409.

[‖‖] Rose, Gehlen's *Jour.* v. 44. The volatile matter was not pure water. It had a peculiar smell, and contained an acid. The analysis of Fourcroy and Vauquelin corresponds well with that in the table.

Clay Family.

XII. Clay Family.

This family contains seven species; not reckoning two minerals, which, for want of a more appropriate place, may be put under it. These are float-stone and alum-stone.

Sp. 1. *Pure Clay* *.

This mineral, which has been found only at Halle in Saxony, and which some mineralogists consider as an artificial production, obtained by decomposing alum by means of lime, occurs in small kidney-form pieces, immediately under the soil in a garden, and is often mixed with sulphate of lime. Colour snow white, sometimes verging on yellowish white. Lustre 0. Fracture very fine earthy. Fragments very blunt-edged. Opaque. Soils very little. Hardness 4. Light. Feels fine, but meagre.

Sp. 2. *Porcelain Earth* †.

Kaolin of the Chinese.

This mineral, from the situation which it occupies, is considered as analogous to felspar, differing chiefly in the state of aggregation. Felspar indeed seems sometimes to be converted into it by exposure to the weather.

Colour reddish white, sometimes inclining to yellowish and greyish white. Massive and disseminated.

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* Kirwan, i. 175.—Brochant, i. 318.—Jameson, i. 294.

† Kirwan, i. 178.—Brochant, i. 320.—Hauy, ii. 616.—Jameson, i. 297.

Particles fine dusty. Colours strongly. Slightly cohering. Feels fine, but meagre. Scarcely adheres to the tongue. Specific gravity from 2·23 to 2·4. Does not fuse *per se*.

Sp. 3. *Common Clay* *.

Clay is a mixture of alumina and silica in various proportions. The alumina is in the state of an impalpable powder; but the silica is almost always in small grains, large enough to be distinguished by the eye. Clay, therefore, exhibits the character of alumina, and not of silica, even when this last ingredient predominates. The particles of silica are already combined with each other; and they have so strong an affinity for each other, that few bodies can separate them; whereas the alumina, not being combined, readily displays the characters which distinguish it from other bodies. Besides alumina and silica, clay often contains carbonate of lime, of magnesia, barytes, oxide of iron, &c. And as clay is merely a mechanical mixture, the proportion of its ingredients is exceedingly various.

Werner, for the conveniency of description, has subdivided common clay into four subspecies, namely, *loam, potter's clay, variegated clay*, and *slate clay*.

Subspecies 1. *Loam.* This may be considered as a very impure potter's clay, mixed with mica and iron ochre. Colour yellowish grey, often spotted yellow and brown. Occurs in masses. Lustre 0; sometimes 1, from scales of mica. Fracture *in the great*, uneven; *in the small* fine earthy. Fragments very blunt-edged.

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* Kirwan, i. 176.—Jameson, i. 301.

Colours a little. Between loose and cohering. Adheres pretty strongly to the tongue. Feels slightly greasy. Not heavy.

Clay Family.

Subspecies 2. *Potter's Clay.* This mineral, which occurs in great abundance in different countries, is used for the various purposes of pottery. Hence the name by which it is distinguished. There are two kinds of it, which Werner describes separately; namely, common potter's clay and pipe-clay.

1. Common Potter's Clay occurs in large rock masses and in beds. Colours yellowish and greyish white; greenish, bluish, and smoke grey. Fracture *in the great*, coarse-grained uneven; *in the small*, pretty fine earthy. Fragments blunt-edged. Opaque. Colours a little. Very soft, passing into loose. Adheres strongly to the tongue. Feels a little greasy. Rather light.

There is a variety of potter's clay which Werner distinguishes by the name of *slaty*. Colour dark ash grey. Principle fracture imperfect conchoidal; cross fracture earthy. Fragments tabular. Rather light, and feels more greasy than common potter's clay; in other particulars it agrees with it.

2. Pipe-Clay. Colour greyish white, passing into yellowish white. Massive. Lustre 1. Fracture *in the great*, coarse or fine-grained uneven; *in the small*, fine earthy. Fragments sharp-edged. Lustre of the streak 3. Between loose and cohering. Adheres pretty strongly to the tongue. Feels rather greasy. Frangibility 4. Rather light *.

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* Jameson. i. 307.

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Subspecies 3. *Variegated Clay.* This mineral is found in Upper Lusatia. Colours white, red, and yellow, which appear in stripes and spots. Massive. Fracture earthy ; sometimes tending to slaty. Lustre in the first case 0, in the second 1. Lustre of the streak 3. Very soft, passing into friable. Feels a little greasy. Adheres a little to the tongue. Sectile. Light [*].

Subspecies 4. *Slate Clay.* This mineral occurs frequently along with coal, and in the floetz trap formation. Colour smoke, yellowish, and ash grey ; greyish black. Massive. Lustre 0 ; sometimes 1, from particles of mica intermixed. Fracture slaty ; sometimes approaches earthy. Fragments tabular. Opaque. Soft. Sectile. Frangibility 4. Specific gravity, according to Kirwan, from 2·6 to 2·68. Adheres slightly to the tongue. Softens and breaks to pieces in water [†].

Sp. 4. *Clay-Stone* [‡].

This mineral occurs in considerable quantities on the top of several of the Pentland hills, in the neighbourhood of Edinburgh, and likewise in other parts of Scotland, and in Germany.

Colours greenish, bluish, ash, smoke, and pearl grey ; brownish red. Sometimes spotted or striped. Massive. Lustre 0. Fracture usually fine earthy ; sometimes passing into fine-grained uneven, into slaty, and into splintery. Fragments seldom tabular, not sharp-edged. Opaque. Soft. Frangibility 4. Does not adhere to the tongue. Feels rather meagre.

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[*] Jameson, i. 308.

[†] Ibid. p. 312.

[‡] Ibid. p 310.

Clay Family.

Sp. 5. *Adhesive Slate* *.

Klebschiefer of Werner.

This mineral occurs at Menil Montagne, near Paris, and has been by most mineralogists confounded with the next species. It is found in beds. Colour light yellowish grey, inclining to greenish. Internal lustre 0. Fracture *in the large*, slaty; *in the small*, fine earthy. Fragments slaty. Opaque. Lustre of streak 3. Sectile. Very soft. Frangibility 4. Exfoliates easily. Adheres strongly to the tongue. Specific gravity as ascertained by Klaproth, 2·080. Absorbs water with avidity, air bubbles separating with a crackling noise †.

Sp. 6. *Polishing Slate* ‡.

This mineral occurs near pseudo volcanoes, and is supposed by Werner to be composed of the ashes of pit-coal, washed down and regularly deposited. Hitherto it has been found only in Bohemia. Colour yellowish grey, approaching cream yellow and yellowish

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* Klaproth, ii. 170.—Jameson, ii. 550.—Brochant, i. 376.—Hauy, iv. 449.

† There is a mineral described by Haberle and analysed by Bucholz under the name of *Saugschiefer*, *sucking slate*, Gehlen's *Jour.* Second Series, ii. 31. It differs very much from adhesive slate, both in its properties and composition. But it is difficult to say, without a more detailed description than Haberle has given, whether it ought to constitute a particular species, or be only a variety of some species already known. It is found in the newest floetz rocks. Haberle divides it into two varieties; the first is soft enough to yield to the nail of the finger, the second hard enough to scratch glass. It is composed nearly of 9 parts silica and 1 part water, yielding traces of alumina, lime, and oxide of iron.

‡ Jameson, i. 315.

white. Always striped, and the colours alternate in layers. Massive. Lustre 0. Principal fracture slaty; cross fracture earthy. Fragments usually tabular. Very soft. Adheres to the tongue. Feels fine, but meagre. Rather light. Specific gravity, before it imbibes water, only from 0·590 to 0·606. After it has imbibed water, its specific gravity becomes from 1·909 to 1·911 [*].

Sp. 7. *Tripoli* [†].

This mineral occurs in veins and beds along with coal, and in floetz trap rocks. Colour yellowish grey, which passes into ash grey. Massive. Internal lustre 0. Fracture pretty coarse earthy. Fragments blunt-edged. Very soft. Feels meagre and rough. Does not adhere to the tongue. Specific gravity from 2·080 to 2·529. Used for polishing.

Sp. 8. *Float-Stone* [‡].

This mineral has hitherto been found only at St Omer, near Paris. Colour light yellowish grey, which inclines to yellowish and greyish white. Occurs tuberose, and is porous. Lustre 0. Fracture earthy. Fragments blunt-edged. Very soft. Rather brittle. Feels rough, and emits a creaking sound. Very light.

Sp. 9. *Alum-Stone* [§].

This mineral occurs at Tolfa, near Rome, where it is

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[*] Haberle, Gehlen's *Jour.* Second Series, ii. 29.

[†] Kirwan, i. 202.—Brochant, i. 379.—Jameson, i. 317.

[‡] Jameson, ii. 552.

[§] Brochant, i. 381.—Jameson, i. 319.—Klaproth, Gehlen's *Jour.* vi. 35.—Gay-Lussac, *Ann. de Chim.* lv. 266.

Clay Family.

said to constitute a hill. From it the famous Roman alum is made.

Colour greyish white, sometimes light yellowish grey. Massive. Lustre 0, and sometimes (scarcely) 1. Fracture uneven, approaching to fine earthy. Fragments blunt-edged. Rather hard. Does not adhere to the tongue. Rather heavy.

The following Table exhibits the constituents of the different species belonging to the clay family, as far as they have been hitherto ascertained.

	Pure Clay.			Porcelain Earth.			Potter's Clay.	Adhesive slate.			Alum-Stone.			Polishing Slate.
	*	†	‡	§	‖	¶	**	††	‡‡	§§	‖‖	¶¶	***	‡‡‡
Silica	0·45	2	1	62	55	52	43·5	66·5	62·50	58	24·00	56·5	62·25	79
Alumina	32·5	45	31	19	27	47	33·2	7	0·50	5	43·92	19·0	17·50	1
Lime	0·35	2	0 5	12	2		3·5	1·25	0·25	1·5				1
Magnesia								1·5	8	6·5				
Potash											3·08	4·0	1·00	
Oxide of Iron	0·45		0·5		0·5	.0 33	1	2·5	4	9				4
Sulphuric acid	19·35		21·5								25·00	16·5	12·50	
Water	47	27	45		14		18	19	22	19	4·00	3·0	3·00	14
Sulph. of lime		24												
Sulph. of bar.				7										
Charcoal									0·75					
Loss			0·5		1·5	0 67	0·8	2·25	2	1		1·0	1·75	1
	100·1	100	00	100	100	100	100	100	100	100	100	100	100	100

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[*] Simon, Gehlen's *Jour.* i. 671. [†] Fourcroy, *Ann. de Mus. Nat.* i. 43. [‡] Bucholz, Gehlen's *Jour* iv. 446. The result of Bucholz and Simon has been confirmed by Gehlen (*Jour.* i. 673.) and Chenevix (*Ann. de Chim.* liv. 200.) The specimen examined by Fourcroy must have contained an unusual proportion of sulphate of lime. [§] Hassenfratz, *Ann. de Chim.* xiv. 144. [‖] Vauquelin, *Bull Phil.* No. xxvi. [¶] Rose, Jameson's *Min.* i. 298. [**] Vauquelin, *Bull. Phil.* No. xxvi. [††] Klaproth, *Beitrage*, ii. 171. [‡‡] A more accurate analysis by Klaproth, *Beitrage*, iv. 314. [§§] Bucholz, Gehlen's *Jour.* Second Series, ii. 37. [‖‖] Vauquelin, Gehlen's *Jour.* vi. 44. [¶¶] Klaproth, Ibid. From these analyses, it appears that the alum-stone of Tolfa contains in itself all the constituents of alum. Hence, probably, the superiority which the alum obtained from it originally possessed; especially as the mineral does not appear to contain any foreign substance which can injure the purity of the alum. For a short sketch of the process followed at Tolfa, the reader is referred to Klaproth, Gehlen's *Jour.* vi. 37. [***] From Hungary, Klaproth, *Beitrage*, iv. 253. [‡‡‡] Bucholz, Gehlen's *Jour.* Second Series, ii. 28.

Clay-slate Family.

XIII. Clay-Slate Family.

This family, like the preceding, consists rather of minerals, the constituents of which are mechanically mixed than chemically combined; but in it the combination is more intimate, and, as we advance, becomes nearer and nearer the state of chemical union. It comprehends five species; namely, *alum-slate*, *bituminous shale*, *drawing-slate*, *whet-slate*, and *clay-slate*.

Sp. 1. *Alum-Slate*[*].

This mineral occurs in beds and strata in the newest clay-slate, and in transition mountains. Werner divides it into two subspecies, *the common* and the *glossy*, distinguished chiefly by their lustre.

Subspecies 1. *Common Alum-Slate*. This mineral occurs massive, and sometimes in balls. Colour between greyish and bluish black, falling strongly into grey. Internal lustre 1. Fracture perfect straight slaty. Fragments tabular. Retains its colour in the streak; becomes a little shining. Soft. Not particularly brittle. Frangibility 4. When exposed to the air, effloresces and acquires an aluminous taste.

Subspecies 2. *Glossy Alum-Slate*. Massive. Colour between bluish and iron black. In the rents exhibits colours resembling tempered steel and the peacock's tail. Lustre of the principal fracture 3, and semimetallic; of the cross fracture 1. Fracture partly straight, partly wave slaty. Fragments tabular, often running

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[*] Jameson, i. 323.

into wedge-shaped. In other respects resembles the former subspecies.

Sp. 2. *Bituminous Shale* *.

This mineral, which occurs along with coal, seems to be a mixture of clay and bitumen. Massive. Colour brownish black. Internal lustre 1. Fracture perfect straight slaty. Fragments tabular. Colour of streak not altered, but lustre 3. Very soft. Rather sectile. Feels greasy. Frangibility 4. When laid on burning coals, it emits a pale flame and burns white.

Sp. 3. *Drawing-Slate, or Black Chalk* †.

This mineral occurs in the primitive mountains, and is usually accompanied by alum-slate. It is employed in drawing ; hence the name.

Colour greyish black, sometimes approaching to bluish black. Massive. Lustre of the principal fracture 1 ; of the cross fracture 0. Principal fracture slaty ; cross fracture fine earthy. Fragments usually tabular. Opaque. Stains paper black. Colour of streak unchanged ; its lustre 2. Soft. Sectile. Frangibility 4. Feels meagre, but fine. Specific gravity 2·144 to 2·77. Burns red. Does not fall to pieces in water.

Sp. 4. *Whet slate* ‡.

Novaculite of Kirwan.

This mineral is found in Germany, and on the Levant, from which it is brought under the name of *Turkey hone stone.*

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* Kirwan, i. 183.—Brochant, i. 389.—Jameson, i. 325.

† Kirwan, i. 112.—Brochant, i. 391.—Jameson, i. 328.

‡ Kirwan, i. 238.—Brochant, i. 393.—Jameson, i. 331.

Clay-slate Family.

Common colour greenish grey; but it occurs also mountain, asparagus, olive, and oil green. Massive. Internal lustre 1, 0. Fracture *in the large*, slaty; *in the small*, splintery. Fragments tabular. Transparency 1. Semihard. Feels rather greasy. Specific gravity 2·722.

Sp. 5. *Clay-Slate*[*].

Argillaceous schistus—Argillite of Kirwan.

This mineral is very widely distributed, constituting a part both of primitive and transition mountains. Colours yellowish, bluish, greenish, smoke, ash, and pearl grey; blackish green; greyish black; brownish red; Sometimes spotted. Massive. Internal lustre 2, 3, 1, resinous, approaching to pearly. Fracture more or less slaty; in some varieties approaching foliated, in others compact. Fragments tabular, and likewise splintery. Streak usually greyish white. Opaque. Soft. Sectile. Sometimes feels a little greasy. Frangibility 4. Specific gravity from 2·67 to 2·88.

We are not possessed of accurate analyses of any of the minerals belonging to this family, except drawing-slate, which according to Wiegleb is composed of

Constituents.

Silica	64·50
Alumina	11·25
Charcoal	11·00
Oxide of iron	2·75
Water	7·50
Loss	3·00
	100·00[†]

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[*] Kirwan, i. 234.—Brochant, i. 395.—Jameson, i. 334.

[†] Crell's *Annals*, 1797, ii. 487.

XIV. MICA FAMILY.

This family consists of five species; namely, *lepidolite, mica, pinite, pot-stone,* and *chlorite.*

Sp. 1. *Lepidolite*[*].

This stone appears to have been first observed by the Abbé Poda, and to have been first described by De Born[†]. Hitherto it has been found only at Rosena in Moravia, where it occurs in gneiss, and Sudermania in Sweden[‡], where it is mixed with quartz; unless the mineral analysed by Trommsdorf, under the name of *white lepidolite,* should belong to this species[§].

Colour peach blossom red, verging on lilac blue; passes into pearl and yellowish grey. Massive. Internal lustre 2, 3. Fracture in the small foliated, in the great splintery. Fragments blunt-edged. Transparency 2. Sectile. Hardness 4 to 5. Not easily pulverized[||]. Specific gravity from 2·816 to 2·8549[¶]. Powder white with a tint of red[||]. Before the blowpipe froths and melts easily into a white semitransparent enamel full of cells. Dissolves in borax with effervescence, but communicates no colour[||]. Effervesces slightly with soda, and melts into a mass spotted with red; with microcosmic salt into a pearl-coloured globule[**].

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[*] Kirwan, i. 208.—Klaproth, *Beitrage,* i. 279, and ii. 191.—Brochant, i. 399.—Hauy, iv. 375.—Jameson, i. 338.—Lelievre, *Jour. de Min.* No. li. 221.

[†] Crell's *Annals,* 1791, ii. 196.

[‡] Hauy.

[§] Gehlen's *Jour.* i. 383.

[||] Lelievre, *Jour. de Min.* No. li. 219.

[¶] Klaproth and Hauy.

[**] Klaproth, *Ann. de Chim.* xxii. 37.

Mica Family.

This mineral was first called *lilalite*, from the resemblance of its colour to that of the lily. Klaproth, who ascertained its composition, gave it the name of *lepidolite*, or *scale-stone*, from its structure.

Sp. 2. *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 2¼ yards square †.

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 in short six-sided prisms ; but it is much more frequently in plates or scales of no determinate figure or size ‡.

Colours yellowish, ash, and greenish grey ; blackish green ; silver white ; pinchbeck brown ; brownish black. Lustre of the crystals 4. Internal lustre 3, 4 ; usually pearly or resinous ; sometimes semimetallic. Fracture perfect foliated, with a single cleavage ; sometimes radiated. Fragments usually tabular. The foliated varieties occur in granular distinct concretions, the radiated in wedge-shaped distinct concretions.

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* Kirwan, i. 210.—Gmelin, *Nov. Com. Petropol.* xii. 549.—Hauy, iii. 208.—Brochant, i. 402.—Jameson, i. 341.

† *Hist. General de Voyages*, t. xviii. 272. quoted by Hauy, *Jour. de Min.* No. xxviii. 299.

‡ Hauy, *Jour. de Min.* No. xxviii. 296.

Transparency of the thin plates 4. Hardness 6. Very tough. The lamellæ flexible, and somewhat elastic. Often absorbs water. Specific gravity from 2·6546 to 2·9342. Feels smooth, but not greasy. Powder feels greasy. 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 [†].

Sp. 3. *Pinite* [‡].

Micarell of Kirwan.

This mineral has been hitherto found only in the mine called Pini, at Schneeberg in Saxony; hence its name.

Colour blackish grey; but often covered with iron ochre on the surface. Almost always crystallized in six-sided prisms, having their lateral edges and angles truncated. Surface of the crystals smooth. Internal lustre 2, resinous; longitudinal fracture small-grained uneven; cross fracture imperfect foliated. Fragments sometimes blunt-edged. Transparency 1. Hardness 6. Sectile. Frangibility 4. Specific gravity 2·980 [§]. At 153° Wedgewood, melts into a black compact glass with a reddish surface [||]. Infusible before the blow-pipe.

Sp. 4. *Pot-stone* [¶].

This mineral is found in beds at Como, in the coun-

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[*] Hauy, *Jour. de Min.* No. xxviii. p. 295. Bergman, however, found pure mica infusible *per se*.

[†] Ibid.

[‡] Kirwan, i. 212.—Brochant, i. 456.—Jameson, ii. 552.

[§] Kirwan.

[||] Kirwan, *Mineral.* i. 212.

[¶] Kirwan, i. 155.—Brochant, i. 405.—Jameson, i. 345.

try of the Grisons. It is said also to have been discovered in other places.

Colour greenish grey. Massive. Internal lustre 2, pearly. Fracture sometimes curve-foliated, sometimes imperfect slaty. Fragments tabular. The foliated shows imperfect granular distinct concretions. Transparency 1, 0. Hardness 4 to 6. Sectile. Feels greasy. Frangibility 6. Very refractory, and therefore used for lining furnaces. May be easily turned into culinary utensils; hence the name.

Sp. 5. *Chlorite* *.

This mineral occurs abundantly in primitive rocks and the older veins. Werner has divided it into four subspecies.

Subspecies 1. *Chlorite Earth.* This mineral is found in different parts of Germany and Switzerland, chiefly in clay-slate. Colour between mountain and blackish green. Composed of small scales. Lustre 1, pearly. Streak mountain green and shining. Adheres strongly to the skin. Feels rather greasy. Rather light. It bears a strong resemblance to green earth.

Subspecies 2. *Common Chlorite.* Found in different parts of Saxony. Colour blackish green. Massive. Internal lustre 1, 2. Fracture foliated, passing into earthy. Fragments blunt-edged. Colour of the streak lighter green. Hardness 5. Opaque. Sectile. Feels rather greasy. Frangibility 4.

Subspecies 3. *Chlorite Slate.* Occurs in beds subordinate to clay-slate. Colour blackish green. Mas-

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* Kirwan, i. 137.—Brochant, i. 408.—Jameson, i. 347.

sive. Internal lustre 2, resinous. Fracture curve slaty; those varieties that have the greatest lustre pass into scaly foliated. Double cleavage. Fragments slaty. Opaque. Streak mountain green. Sectile. Feels rather greasy. Heavier than common chlorite.

Subspecies 4. *Foliated Chlorite.* Hitherto found only at St Gothard in Switzerland, and in the island of Java[*]. Colour between mountain and blackish green. Massive; but usually crystallized in six-sided tables, cylinders terminated by two cones, and in double cones with the bases joined. Surface streaked. External lustre 2; internal 3, pearly. Fracture foliated. Cleavage simple. Fragments tabular. Transparency 1, 0. Soft. Sectile. Folia usually flexible. Feels rather greasy. Frangibility 4. Streak light-coloured.

The following Table exhibits the constituents of the preceding species, as far as they have been hitherto ascertained.

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[*] Jameson's *Mineralogy of the Scottish Isles.*

Mica Family. Constituents.

	Lepidolite.				Mica.		Pinite.	Chlorite Earth.	Common Chlorite.		Foliated Chlorite.
	*	†	‡	§	‖	¶	**	††	‡‡	§§	‖‖
Silica	54·50	54	56	52	48	50	29 5	50	26	41·15	35
Alumina	38·25	20	18	31	37	35	63·0	26	18 5	6·13	18
Lime			3	8·50	1·5	1·33		1·5		1·5	
Magnesia					1·5	1·35			8	39·47	29·9
Ox. of Iron	·75	1	4	0·25	6	7	6·75	5	43	10·15	9·7
Ox. of mang.		3									
Potash	4	18	8	7				17·5			
Mur. of potash									2		
Fluate of lime		4									
Water			6		5					1·50	2·7
Loss	2·50		5	1·25	1	5·32	0·75		2·5	0·10	4·7
	100	100	100	100	100	100	100	100	100	100	100

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* Klaproth, *Beitrage*, ii. 195. † Vauquelin, *Jour. de Min.* No. li. 235.

‡ Vauquelin, *Jour. de Phys.* lii. 345. The mineral analysed is called *white chorlite*; but it seems to be the same in its constituents as lepidolite.

§ Trommsdorf, Gehlen, i. 383. This is described as a white lepidolite, and seems to be the same mineral as Vauquelin's white chlorite.

‖ Chenevix, *Ann. de Chim.* xxviii. 200. It is called *talc* by Chenevix, but was obviously *mica*. Klaproth has lately analysed mica, and found it to contain 16 *per cent.* of potash. Nicholson's *Jour.* xxiii. 158.

¶ Vauquelin, Hauy, iii. 210. ** Klaproth, *Beitrage*, ii. 227.

†† Vauquelin, Hauy, iii. 266. Under the potash is included a little muriatic acid. ‡‡ Vauquelin, Ibid. p. 264.

§§ Hœpner, Crell's *Annals*, 1790, i. 56. ‖‖ Lampadius, *Handbuch*

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Chap. II.

XV. TRAP FAMILY.

THE species belonging to this family are six in number; namely, *diaspore*, *hornblende*, *basalt*, *wacke*, *clinkstone*, and *iron-clay*. Lava may be likewise referred to it, as it is formed by the action of fire on rocks chiefly belonging to this family.

Sp. 1. *Diaspore* *.

This mineral was first noticed by Lelievre, and described by Hauy. Nothing is known concerning the part of France where it was found. Its colour is grey. It occurs in masses composed of plates slightly curved, and easily separable from each other. Lustre considerable, pearly. Divisible into plates in another direction, forming with the first an angle of 130°. Scratches glass. Before the flame of a candle decrepitates, and disperses in small pieces †. Specific gravity 3·4324.

Sp. 2. *Hornblende* ‡.

Amphibole of Hauy.

This mineral enters into the composition of many mountains. It is often amorphous, but frequently also crystallized. The primitive form of its crystals is a rhomboidal prism, the faces of which are inclined at

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zur Chemischen Analysen der Mineral Korper, p. 229. The great differences in the analyses of chlorites render it doubtful how far the minerals examined have been real chlorites.

* Hauy's *Mineralogie*, iv. 358.—Brochant's *Mineralogie*, ii 507.—Vauquelin, *Ann. de Chim.* xlii. 113.

† Hence the name given to it by Hauy.

‡ Kirwan, i. 213.—Hauy, iii. 58.—Brochant, i. 415.—Jameson, i. 356.

Trap Family.

angles of 124° 34′ and 55° 26′, and whose bases have angles of 122° 56′ and 57° 4′. The most common variety is a six-sided prism, terminated by trihedral or tetrahedral summits. Werner divides it into four subspecies.

Subspecies 1. *Common Hornblende*. This mineral forms one of the constituents of the rocks called syenite and green stone. Colour greenish black, sometimes approaching to grey and velvet black; sometimes to greenish grey. Massive, and sometimes crystallized in prisms which intersect each other, so that it is difficult to determine their figure. Internal lustre 3, 4, pearly. Fracture usually foliated, sometimes radiated. Surface of the fracture streaked longitudinally. Cleavage of the foliated varieties double. Fragments usually indeterminate; sometimes approach the rhomboidal. In granular distinct concretions. Transparency of the black 0, of the green 1. Streak mountain green. Hardness 8 to 6. Frangibility 1. Specific gravity 3·6 to 3·83. When moistened, exhales a bitter smell. Before the blow-pipe melts into a black glass.

Subspecies 2. *Labradore Hornblende*. This mineral is found in the island of St Paul, on the coast of Labradore. Colour brownish black, greenish black, copper red, and greyish black. Massive and in rolled pieces. Internal lustre from 1 to 3, semimetallic. Fracture foliated. Cleavage double. Fragments sometimes rhomboidal. In lamellar distinct concretions. Opaque. Hardness 7. Frangibility 4. Specific gravity 3·3857.

Subspecies 3. *Hornblende-Slate*. Occurs in beds in clay-slate, and is very common. Colour between greenish and raven black. Massive. Internal lustre 3, 2, pearly. Fracture in the great, slaty; in the small,

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promiscuous radiated. Fragments sometimes tabular. Streak greenish grey. Hardness 6. Frangibility 3.

Subspecies 4. *Basaltic Hornblende.* Found imbedded in basalt and wacke. Colour velvet black. Always in single crystals. The form of the crystals is that described under the general character of the species; for the amphibole of Hauy refers particularly to this subspecies. Surface smooth. Lustre of the principal fracture 4; of the cross fracture 2; vitreous. Principal fracture perfect straight foliated, with a double obliquely intersecting cleavage. Cross fracture fine-grained uneven. Opaque. Hardness 7. Pretty brittle. Frangibility 4. Specific grevity 3·250 *. Melts into a black glass, but is more refractory than common hornblende.

Sp. 3. *Basalt* †.

This mineral is confined to the floetz trap formation, but occurs abundantly in almost every country, and in none is it more common than in Scotland. Colours greyish black; ash grey, inclining to brown; sometimes nearly raven black. Massive. Internal lustre commonly 0; sometimes 1, from foreign particles. Fracture usually coarse-grained uneven; sometimes imperfect large conchoidal and fine splintery. Fragments not sharp-edged. Mostly in columnar distinct concretions of various sizes, sometimes in globular distinct concretions; sometimes tabular. Transparency usually 0; sometimes 1. Streak light ash grey. Hardness 8, 9. Brittle. Frangibility 1. Specific gravity from 2·864 to 3·00. Melts before the blow-pipe into an opaque black glass.

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* Hauy.

† Kirwan, i. 231.—Brochant, i. 430.—Jameson, i. 369

Sp. 4. *Wacke*[*].

This species, like the preceding, is confined to the floetz trap formation, and occurs in beds and veins. It constitutes the basis of amygdaloid.

Colour greenish grey of various degrees of intensity. Massive and vesicular. Lustre 0, or scarcely 1. Fracture even; sometimes imperfect flat conchoidal, sometimes uneven and earthy. Fragments blunt-edged. Never in distinct concretions. Opaque. Lustre of streak 3. Sectile. Soft. Frangibility 4. Specific gravity 2·535 to 2·893. Melts like basalt.

Sp. 5. *Clink-Stone*[†].

This mineral, like the preceding, belongs to the floetz trap formation, and is common in Germany, Scotland, &c.

Colour dark greenish grey, sometimes passing into yellowish and ash grey. Massive. Lustre of the cross fracture 1, 0; of the principal fracture 1, 2. Cross fracture splintery; passing into conchoidal and even; principal fracture slaty. Fragments mostly sharp-edged, sometimes tabular. In irregular columnar and tabular distinct concretions. Transparency 1. Hardness 7 to 9. Brittle. Frangibility 4. Specific gravity 2·575[‡]. When struck with a hammer sounds like a piece of metal. Melts easily, and gives a glass nearly colourless.

Sp. 6. *Iron Clay*[§].

This mineral likewise belongs to floetz trap forma-

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[*] Kirwan, i. 223.—Brochant, i. 434.—Jameson, i. 376.

[†] Brochant, i. 437.—Klaproth, iii. 229.—Jameson, i. 380.

[‡] Klaproth.

[§] Jameson, ii. 603.

tion, and seems till lately to have been confounded with wacke. It was named by Werner from the great proportion of peroxide of iron which it contains.

Colour brownish red; sometimes approaching reddish brown and blood red. Almost always contains vesicles. Internal lustre 0. Fracture fine earthy; sometimes inclining to conchoidal. Soft. Frangibility 3. Moderately heavy.

The following Table exhibits the constituents of the preceding species, as far as they have been ascertained by analysis:

Constituents.

	Diaspore.	Common Hornblende.		Basaltic Hornblende.		Basalt.		Clinkstone.
	*	†	‡	§	§	‖	¶	**
Silica		37	42	42	50	48	44·5	57·25
Alumina	80	27	7·69	7·69	0·77	16	16·75	23·5
Lime		5	9·8	8·8	9·75	9	9·5	2·75
Magnesia		3	10·9	10·9	19·25		2·25	
Potash					0·5			
Soda						4	2·6	8·1
Oxide of iron	3	25	22·69	22·69	11	16	20	3·25
Oxide of mang.			1·15	1·15	0·5		0·12	0·25
Ox. of chrome.					3			
Muriatic acid						1		
Water	17			5·77	5·25	5	2	3
Loss		3	5·72	1		1	2·28	1·9
	100	100	100	100	100	100	100	100

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* Vauquelin, *Ann. de Chim.* xlii. 113. † Hermann, *Beob. der Berlin*, v. 317. ‡ Laugier, *Ann. de Mus. de Hist. Nat.* v. 79.

§ Laugier, Gehlen, iv. 538. ‖ Kennedy, *Edin. Trans.* v. 89.

¶ Klaproth, *Beitrage*, iii. 253. He found also traces of muriatic acid.

** Klaproth, iii. 229.

Lithomarge Family.

XVI. Lithomarge Family.

This family consists of five species; namely, *green earth*, *lithomarge*, *rock-soap*, *umber*, and *yellow earth*: They are all soft and soapy, and seem rather mechanical mixtures than chemical compounds.

Sp. 1. *Green Earth*[*].

This mineral occurs in balls and crusts in amygdaloid. Colour seladon green; sometimes passing into other varieties. Massive and in globular pieces. Internal lustre 0. Fracture even. Fragments blunt-edged. Lustre of streak 2. Very soft. Sectile. Frangibility 4. Light. Used by painters, as the colour is not altered by acids.

Sp. 2. *Lithomarge*[†].

This mineral is found in veins, cavities, and beds, in various kinds of rocks, and is far from uncommon. Werner divides it into two subspecies.

Subspecies 1. *Friable Lithomarge.* Colours snow, yellowish, and reddish white. Massive. Lustre scarce 1. Generally coherent, sometimes loose; composed of fine scaly particles. Feels greasy. Adheres to the tongue.

Subspecies 2. *Indurated Lithomarge.* Colours snow, yellowish, and reddish white; pearl grey; plum and lavender blue; flesh red and ochre yellow. The white and red varieties have only one colour; the others spot-

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[*] Kirwan, i. 196.—Brochant, i. 445.—Jameson, i. 388.

[†] Kirwan, i. 187.—Brochant, i. 447.—Jameson, i. 390.

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ted and clouded. Massive. Internal lustre 0. Fracture large conchoidal. Lustre of streak 3. Very soft. Sectile. Frangibility 4. Adheres strongly to the tongue. Feels greasy. Light.

Sp. 3. *Rock-soap* *.

This mineral has been hitherto found only at Olkuzk in Poland, in Cornwall, the Isle of Sky, and always imbedded in rocks belonging to the floetz trap formation.

Colour pitch or brownish black. Massive. Lustre 0. Fracture fine earthy. Fragments blunt-edged. Opaque. Does not soil. Writes well. Lustre of streak 3, resinous. Very soft. Sectile. Frangibility 4. Adheres strongly to the tongue. Rather light.

Sp. 4. *Umber* †.

This mineral occurs in beds in the island of Cyprus. Colour between liver and dark yellowish brown. Massive. Fracture large conchoidal. Fragments blunt-edged. Very soft. Adheres a little to the tongue. Feels meagre. Light. Used as a pigment.

Sp. 5. *Yellow Earth* ‡.

This mineral occurs in Upper Saxony along with iron-stone in the floetz clay formation. Colour ochre yellow. Massive. Lustre of the principal fracture 1; of the cross fracture 0; of the streak 3. Principal fracture more or less perfect slaty; cross fracture earthy. Fragments partly indeterminate and blunt-

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* Brochant, i. 453.—Jameson, i. 395.—Bucholz, Gehlen's *Jour.* iii. 597.

† Jameson, ii. 554.

‡ Kirwan, i. 294.—Brochant, i. 455.—Jameson, i. 397.

Soapstone. Family.

edged, partly tabular. Soils. Writes. Very soft. Adheres strongly to the tongue. Feels a little greasy. Light. Used as a pigment.

Constituents.

Only two of these species have been analysed; namely, green earth and rock-soap. The following are their constituents:

	Green Earth.				Rock Soap.
	*	†	‡	§	‖
Silica	53	53	51·5	51·0	44·0
Alumina	12			12·0	26·5
Lime	2·5			2·5	0·5
Magnesia	3·5	2	1·5	3·5	
Oxide of iron	17	28	20·5	17·0	8·0
Potash		10	18		
Soda				4·5	
Water	11	6	8	9	20·5
Loss	1	1	0·5	0·5	5
	100	100	100	100	100

As some of these analyses are not accompanied by descriptions, it is uncertain how far they belong to the green earth and rock-soap of Werner.

XVII. SOAP-STONE FAMILY.

To this family belong seven species; namely *native*

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* Klaproth, Gehlen's *Jour.* i. 656.

† Green earth of Verona. Klaproth, *Beitrage*, iv. 239.

‡ From Cyprus. Klaproth, Ibid. p. 242.

§ From New East Prussia. Klaproth, Ibid. p. 244.

‖ Bucholz, Gehlen's *Jour.* iii. 603.

magnesia, *bole*, *cimolite*, *meerschaum*, *fuller's earth*, *steatite*, and *bildstein*.

Sp. 1. *Native Magnesia* [*].

This mineral was discovered by Dr Mitchell in the serpentine rocks at Robschütz in Moravia. A substance probably of the same kind has been described by Giobert as occurring at Baudissero in Piedmont, where it is used as a porcelain earth.

Colour yellowish grey, passing into cream yellow. Marked with blackish brown spots. The Piedmontese is pure white. Massive and tuberose. Internal lustre 0. Fracture in the great, large flat conchoidal; in the small, splintery. Fragments sharp-edged. Soft. The Piedmontese occurs often in pretty hard masses. Not very sectile. Frangibility 3. Feels rather meagre. Adheres a little to the tongue. Rather light.

Sp. 2. *Bole* [†].

This mineral occurs chiefly in the isle of Lemnos, at Sienna in Italy, and in Silesia.

Massive. Fracture perfect conchoidal. Internal lustre 1; of streak 3. Transparency 1, 2, 0. Hardness 4. Sectile. Specific gravity from 1·4 to 2. Acquires a polish by friction. Adheres to the tongue. Feels greasy. Colour cream yellow, passing into brown and flesh red; sometimes spotted brown and black. When dry and put into water, it breaks with a crackling noise.

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[*] Brochant, i. 499.—Jameson, i. 403.—Giobert, *Jour. de Phys.* lx. 249.

[†] Kirwan, i. 191.—Brochant, i. 459.—Jameson, i. 399.

Soap-stone Family.

Sp. 3. *Cimolite* [*].

Found by Hawkins in the isle of Argentiers in the Archipelago, where it is used for whitening stuffs. It was mentioned by Pliny under the name of *cimolia.* Colour pearl grey : when exposed to the air becomes reddish. Texture earthy. Fracture uneven. Opaque. Does not stain. Adheres strongly to the tongue. Soft. Difficultly broken. Specific gravity 2·000. Becomes white before the blow-pipe.

Sp. 4. *Meerschaum* [†].

Kiffekill—*Seaforth.*

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. When thrown on the fire it sweats, emits a fetid vapour, becomes hard and perfectly white.

Colour yellowish white ; rarely snow white. Massive. Internal lustre 0; of the streak 3. Fracture fine earthy, passing into flat conchoidal. Fragments pretty sharp-edged. Opaque. Soft. Sectile. Frangibility 3. Feels a little greasy. Specific gravity 1·600 [‖].

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[*] Brochant, i. 329.—Klaproth, i. 299.

[†] Kirwan's, *Min.* i. 144.—Brochant, i. 462.—Jameson, i. 405.

[‡] Reignegg, *Phil. Mag.* iii. 165.

[§] Hence the name *kiff-kill*, or rather *keff-kelli*, "clay-froth," or "light clay."

[‖] Klaproth.

Sp. 5. *Fuller's Earth* *.

This mineral occurs in greatest perfection in the south of England; it is found also in Upper Saxony and in Sweden.

Colour greenish white, greenish grey, olive and oil green. Sometimes spotted. Massive. Internal lustre dull; of the streak 3. Fracture uneven; sometimes large conchoidal, sometimes splintery. Fragments indeterminate, blunt-edged; also slaty. Usually opaque. Very soft. Sectile. Scarcely adheres to the tongue. Feels greasy. Falls to pieces in water. Melts into a brown spongy scoria.

Sp. 6. *Steatite* †.

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.

It is usually amorphous, but sometimes it is crystallized in six-sided prisms. Colour greyish, greenish, yellowish, and reddish white. Sometimes spotted. Lateral planes of the crystals transversely streaked. Internal lustre 0 or 1; of the streak 3. Fracture coarse splintery; sometimes uneven, conchoidal, and even tending to coarse fibrous. Fragments blunt-edged. Transparency 1, 2. Soft. Sectile. Frangibility 2. Does not adhere to the tongue. Feels greasy. Specific

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* Kirwan, i. 184.—Brochant, i. 464.—Jameson, i. 409.

† Kirwan, i. 151.—Pott, *Mem. Berlin*, 1747, p 57.—Wieglcb, *Jour. de Phys*. xxix. 60.—Lavoisier, *Mem. Par.* 1778, p. 433.—Brochant, i. 474.—Jameson, i. 418.

gravity 2·614. Before the blow-pipe loses its colour and hardens, but does not melt.

Sp. 7. *Bildstein,* or *Figure-Stone*[*].

This mineral, which was originally classed with steatite, is brought from China, and is always cut into various figures; hence the name. The attention of mineralogists was first drawn to it by the analysis of Klaproth.

Colour greenish grey, yellowish grey, yellowish brown; some varieties appear to be of a flesh red colour, and some are spotted. Massive. Internal lustre scarce 1. Fracture perfect splintery. Has a tendency to the slaty. Fragments sometimes indeterminate angular, pretty sharp-edged; sometimes slaty. Transparency 2. Soft, and very soft. Sectile. Feels rather greasy. Specific gravity from 2·785 to 2·815[†].

The following Table exhibits the constituents of these species, as far as they have been ascertained by analysis:

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[*] Jameson, ii. 604.—Klaproth, *Beitrage*, ii. 184.—Vauquelin, *Ann. de Chim.* xlix. 77.

[†] Klaproth.

Book III. Chap. II

	Native Magnesia.		Bole.	Cimolite	Meerchaum.		Fuller's Earth.			Steatite.				Bildstein.		
	*	†	‡	§	‖	‖	¶	**	††	‡‡	‡‡	§§	‖‖	¶¶	¶¶	*⁎*
Silica		15·6	47	63	50·5	41	51·8	53	48·5	59·5	48·0	61·25	64	54	62	56
Alumina			19	23			25·0	10	15·5		14	1	3	36	24	29
Lime					0·5	0·50		0·5				0·75			1	2
Magnesia	51	68			17·25	18·25		1·25	1·5	30·5	20·5	26·25	22			
Oxide of iron	Trace		5·4	1·25			3·7	9·75	7·0	2·5	1	1	5	0·75	0·5	1
Potash																7
Carbonic acid	47·4	12			5											
Sulph. of lime		1·6														
Carb. of lime			5·4				3·3									
Carb. of mag.			6·2				0·7									
Common salt								0·1								
Water		3·0	17	12	25	39	15·5	24	25·5	5·5	15·5	6	6	5·5	10	5
Loss	1·6			0·75	1·75	1·25		1·4		2	1	3·75		3·75	2·5	
	100	100.2	100	100	100	100	100	100	100	100	100	100	100	100	100	100

* Dr Mitchell and Lampadius.—Jameson, i. 404. † Giobert, *Jour. de Phys.* lx. 258. ‡ Bole of Lemnos, Bergman, iv. 157. § Klaproth, *Beitrage*, i. 299. ‖ Klaproth, Ibid. ii. 174 and 175. Under the water in the last analysis is included the carbonic acid gas. ¶ From Hampshire, Bergman, iv. 157. ** From Rygate in Surrey. Klaproth, *Beitrage*, iv. 334. †† From Nimptch in Silesia. Klaproth, Ibid. p. 339. ‡‡ The first from Baireuth, the second from Cornwall. Klaproth, ii. 179, and 183. §§ Craie de Briancon, Vauquelin, *Ann. de Chim* xlix. 83. ‖‖ Vauquelin, Ibid. p. 78. ¶¶ Klaproth, *Beitrage*, ii. 187, and 189. *⁎* Vauquelin, *Ann. de Chim.* xlix. 83.

The striking want of similarity in the composition of steatite and bildstein, notwithstanding the similarity of their external characters, is very remarkable, and shows us that magnesia and alumina may often perform nearly the same functions.

XVIII. TALC FAMILY.

THIS family comprehends five species; namely, *nephrite*, *serpentine*, *schillerstone*, *talc*, and *asbestus*; most of which are divided into subspecies for the convenience of description.

Sp. 1. *Nephrite* *.

Jade.

This stone was formerly called *lapis niphriticus*, 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. Werner divides it into two subspecies, *common nephrite* and *axe-stone*.

Subspecies 1. *Common.* Colour leek green; sometimes greenish white. Massive and in rolled pieces. Lustre usually 0; sometimes 1 and silver white, from particles of talc and asbestus. Fracture coarse splintery; splinters greenish white. Fragments not remarkably sharp-edged. Transparency 2. Hardness 9. Frangibility 2. Feels a little greasy. Somewhat brittle.

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* Kirwan, i. 171.—Bartolin, *De Lapide Nephritico.*—Lehmann, *Nov. Comm. Petropol.* x. 381.—Hœpfner, *Hist. Nat. de la Suisse*, i. 251.—Brochant, i. 467—Jameson, i. 412.

Specific gravity from 2·966 to 3·071 *. Takes a good polish, but has a muddy aspect; cut into handles for knives, &c.

Subspecies 2. *Axe-stone.* Colour between mountain and leek green. Massive. Internal lustre 1. Fracture in the great, slaty; in the small, splintery. Fragments tabular. Transparency 2. Hardness 8. Not very brittle. Frangibility 2. Made into hatchets &c. by the natives of New Zealand †.

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* Saussure, Gehlen's *Jour.* Second series, ii. 453.

† There is a mineral, first noticed by Saussure senior under the name of *jade*, which has been commonly considered as a variety of nephrite, though in all probability it ought to constitute a species apart. Delametherie has called it *lemanite*, and Saussure, junior, has lately described and analysed it under the name of *saussurite* (*Jour. de Min.* xix. 205. and Gehlen's *Jour.* Second Series, ii 458); and Klaproth has analysed it under the name of *Switzerland jade*, (*Beitrage*, iv 271.) Saussure, senior, found it in different parts of the Alps, chiefly on the banks of lakes and rivers, and it has been observed in other places. Colour bluish green, greyish white, and milk white. Massive. Lustre 0. Fracture splintery Transparency 1. Fragments indeterminate, sharp-edged. Hard. Difficultly frangible. Feels meagre. Specific gravity from 3·200 to 3·389. When heated to redness in a crucible it becomes reddish grey. Before the blowpipe the edges melt into a greenish grey glass, but the whole cannot be melted into a bead. Its constituents, according to Saussure and Klaproth's analyses, are as follows:

	Saussure.	Klaproth.
Silica	44	49
Alumina	30	24
Lime	4	10·5
Magnesia		3·75
Oxide of iron	12·5	6·5
Oxide of mangan.	0·05	
Potash	0·25	
Soda	6	5·5
Loss	3·2	0·75
	100	100

Talc Family.

Sp. 2. *Serpentine* [*].

This stone is found in amorphous masses, forming strata, and even entire rocks. It occurs in great abundance in many countries, particularly at Zoblitz in Upper Saxony, and at Portsoy in Scotland, where it is known by the name of *Portsoy marble.* Werner divides it into two subspecies, the *common* and the *precious.*

Subspecies 1. *Common Serpentine.* Colours various shades of green, yellow, and red. Several colours usually occur together in stripes, dots, and clouds. Massive. Internal lustre 1, 0. Fracture sometimes splintery, sometimes large flat conchoidal; and also small-grained uneven, passing into even. Transparency 1. Hardness 6, 7. Passing into sectile. Frangibility 3. Feels a little greasy. Specific gravity from 2·574 to 2·709. Does not melt before the blow-pipe.

Subspecies 2. *Precious Serpentine* Colour dark leek green, passing into blackish green. Massive. Internal lustre 2; sometimes 1, resinous. Fracture conchoidal; sometimes splintery. Fragments in the conchoidal variety very sharp-edged; in the splintery less so. Transparency 2. Feels rather greasy. Soft. Moderately heavy.

Sp. 3. *Schillerstone* [†].

This mineral occurs in beds of serpentine, and seems

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[*] Kirwan, i. 156.—Margraff, *Mem. Berlin*, 1759, p. 3.—Bayen, *Jour. de Phys.* xiii. 46.—Mayer, Crell's *Annals*, 1789, ii. 416.—Brochant, i. 481.—Jameson, i. 421.

[†] Jameson, i. 429.

to be serpentine in a state of crystallization, or nearly so.

Colour olive green. Massive. Lustre 3; passing into semimetallic. Fracture perfect foliated. Cleavage single. Sometimes in coarse-grained distinct concretions. Soft. Slightly brittle. Frangibility 4. Moderately heavy.

Sp. 4. *Talc* *.

This stone has some resemblance to mica, but is easily distinguished from it. It occurs sometimes loose, and sometimes in an indurated form. Werner divides it into three subspecies.

Subspecies 1. *Scaly Talc. Talcite* of Kirwan. This variety occurs in tin veins under the form of small scales, scarcely cohering. Lustre 1 to 2. Pearly. Light. Adheres to the fingers. When rubbed upon the skin it gives it a gloss. Colour between greenish white and greenish grey.

Subspecies 2. *Common Talc ; Venetian Talc.* Occurs imbedded in serpentine. Colour apple green ; greenish and silver white ; asparagus green. Massive, and in very fine delicate tabular crystals. Lustre 4, 3 ; internally pearly or semimetallic. Fracture straight and curved foliated. Fragments wedge-shaped ; seldom splintery. Cleavage single. Transparency 2 ; in thin leaves 4. Sometimes in granular distinct concretions. Leaves flexible, but not elastic. Very soft. Sectile. Frangibility 5. Feels very greasy. Specific gravity from 2·7 to 2·8. Infusible before the blow-pipe with-

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* Kirwan, i. 150.—Pott, *Mem. Berl.* 1746. p. 65.—Hauy, iii. 252.—Brochant, i. 486.—Jameson, i. 430.

out addition. By this property it is distinguished from chlorite.

Subspecies 3. *Indurated Talc.* Occurs, like the preceding, in primitive mountains. Colour greenish grey. Massive. Lustre 3, 2, pearly. Fracture between imperfect foliated and curve-slaty. Fragments slaty, Transparency 1, 2. Soft. Sectile. Frangibility 3. Feels rather greasy. Has a strong resemblance to potstone.

Sp. 5. *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 in primitive mountains, especially in serpentine, which it traverses in veins. Werner divides it into four subspecies.

Subspecies 1, *Elastic Asbestus*, or *Rock-Cork.* Colours yellowish grey; yellowish and greyish white; pale ash grey; yellowish brown and cream yellow. Sometimes shows ochre yellow spots. Massive and in plates. Lustre 1, 0; of streak 3. Fracture very fine promiscuous fibrous, which on a slight inspection appears fine-grained uneven. Opaque, or transparency only 1. Very soft; receives an impression from the nail. Sectile. Flexible and elastic. Frangibility 1. Cracks when handled. Feels meagre. Specific gravity from 0·993 to 0·680 †. Melts with great difficulty before the blow-pipe.

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* Kirwan, i. 159.—Bergman, iv. 160.—Plot, *Phil. Trans.* xv. 1051.—Nebel, *Jour. de Phys.* ii. 62.—Ibid. iii. 367.—Hauy, iii. 245.—Brochant, i. 492.—Jameson, i. 438.

† Bergman.

Subspecies 2. *Amianthus.* Colours greenish white; greenish grey; olive green; sometimes blood red. Massive, and in plates, and in capillary crystals. Internal lustre 2, 3; sometimes 4, pearly. Fracture very delicate parallel fibrous. Fragments thin splintery. Transparency 1, 2. Very soft. Sectile. Flexible and somewhat elastic. Splits easily. Frangibility 2. Specific gravity from 0·9888 to 2·3134. Melts with difficulty before the blow-pipe.

Subspecies 3. *Common Asbestus.* Colours dark leek and mountain green; greenish grey. Massive and in capillary crystals. Internal lustre 2, pearly. Fracture parallel radiated, and parallel curved fibrous. Fragments splintery. Transparency 1, 2. Soft. Frangibility 2. Not flexible. Feels rather greasy. Specific gravity 2·547 to 2·995. Melts with difficulty into a greyish black scoria.

Subspecies 4. *Ligniform Asbestus* or *Rock-Wood.*—Colour wood brown. Massive and in plates. Internal lustre 1. Fracture in the great curve-foliated; in the small promiscuous fibrous. Fragments slaty. Soft. Sectile. Frangibility 2. Somewhat flexible and elastic. Feels meagre. Light.

The following Table exhibits the constituents of the preceding species, as far as they have been analysed:

Talc Family.

Constituents.

	Nephrite.	Serpentine.	Common Talc.	Rock-Cork.		Amianthus.				Common Asbestus.
	*	†	‡	§	§	‖	‖	‖	**	††
Silica	53·75	28	62	62	56·2	64	64	72	59	63 9
Alumina	1·59	23	1·5	2·8	2	2·7	3·3	3·3	3	1·1
Lime	12·75	0·5		10	12 7	13·9	6·9	10·5	9·5	12·8
Magnesia		34·5	27	22	26·1	17·2	18·6	12·9	25	16·0
Ox. of Iron	5	4·5	3·5	3·2	3	2·2	1·2	1·3	2·25	6·0
Ox. of Mang.	2									
Barytes							6			
Potash	8·44									
Soda	10·83									
Water	2·25	10·5	6							
Loss	3·39								1·25	
	100	101	100	100	100	100	100	100	100	100

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* Saussure, *Jour. de Min.* xix. 205.

† Chenevix, *Ann. de Chim.* xxviii. 199. As no description is given, we are uncertain how far the mineral examined was serpentine.

‡ Vauquelin, *Ann. de Chim.* xlix. 77.

§ Bergman, iv. 169, and 170. The lime and magnesia were in the state of carbonates.

‖ Bergman, Ibid. p. 161, 164, and 168. The magnesia and lime were in the state of carbonates. First specimen from Svartvik in Dalecarlia; second from Tarentaise; third from Corias in Asturias.

** Chenevix, *Ann. de Chim.* xxviii. 201.

†† Bergman, iv. 170. From Grænge in Dalecarlia.

XIX. Actinolite Family.

This family comprehends seven species; namely, *actinolite*, *smaragdite*, *tremolite*, *antophyllite*, *cyanite*, *sahlite*, and *schalstone*.

Sp. 1. *Actinolite* *.

Strahlstein of Werner.

This mineral occurs chiefly in beds in primitive mountains. Werner subdivides it into three subspecies.

Subspecies 1. *Asbestous Actinolite.* Colours greenish grey, mountain green, smalt blue, olive green, yellowish and liver brown. Massive and in capillary crystals, which are sometimes a little flexible and elastic. Internal lustre 2, pearly. Fracture between fibrous and narrow radiated. Fragments wedge-shaped. In coarse wedge-shaped distinct concretions. Transparency 1, 0. Soft. Brittle. Frangibility 2. Specific gravity 2·584 to 2·916. Melts before the blow-pipe into a black or grey scoria.

Subspecies 2. *Common Actinolite.* Usual colour leek green; sometimes pistachio and olive green; blackish green. Massive, and crystallized in very oblique six-sided prisms. Primitive form of its crystals, according to Hauy, is a four-sided prism whose bases are rhombs, and which he presumes to be the same with the primitive form of hornblende. Crystals often longitudinally streaked; large and often acicular. External lustre 4; internal 3, between resinous and vitreous. Fracture

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* Brochant, i. 504.—Hauy, iii. 73.—Jameson, i. 455.

Actinolite Family.

commonly radiated, and usually scopiform and diverging; sometimes foliated with an indistinct twofold cleavage. Fragments sometimes wedge-shaped and splintery. In wedge-shaped and granular distinct concretions. Transparency of the massive varieties between 2 and 1; of the crystals 4. Hardness 8. Pretty brittle. Frangibility 2. Specific gravity 3·000 to 3·310.

Subspecies 3. *Glassy Actinolite.* Principal colour mountain green, passing to greenish grey and to emerald green. Massive and in thin six-sided acicular crystals. Lustre 3, vitreous. Fracture promiscuous fibrous, and narrow scopiformly diverging radiated. Fragments splintery and wedge-shaped. In prismatic distinct concretions, inclosing smaller ones. Transparency 2. Brittle. Frangibility 4. Has cross rents. Semihard. Specific gravity from 2·95 to 3·903.

Sp. 2. *Smaragdite* *.

Granular actinolite of Werner—*Diallage* of Hauy.

This mineral has been found in Corsica and in Stiria, and was first noticed by Saussure. Colour grass green; sometimes passing into emerald green. Massive and disseminated. Internal lustre 3. Fracture foliated; cleavage single. In granular distinct concretions. Transparency 2. Hardness 7. Brittle. Specific gravity 3.

Sp. 3. *Tremolite* †.

Grammatite of Hauy.

This mineral occurs chiefly in primitive mountains,

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[*] Brochant, ii. 506.—Hauy, iii. 125.—Jameson, ii. 605.

[†] Brochant, i. 514—Hauy, iii. 227.—Jameson, i. 464.

and usually in lime-stone. It was first observed at Tremola in Switzerland; hence the name. Werner subdivides it into three subspecies.

Subspecies 1. *Asbestous Tremolite.* Colour yellowish white; also greyish, reddish, and greenish white. Massive and in capillary crystals. Internal lustre 2, pearly. Fracture fine fibrous, either straight or scopiform diverging. Fragments splintery and wedge-shaped. In wedge-shaped prismatic concretions. Transparency 1. Very soft. Frangibility 5. Sectile.

Subspecies 2. *Common Tremolite.* Colours greyish, greenish, yellowish, and reddish white; pale asparagus green; dark smoke grey. Sometimes massive, sometimes crystallized. Primitive form of the crystals, according to Hauy, is a rhomboidal prism, whose sides are inclined to each other at angles of 126° 52′ 12″ and 53° 7′ 48″. It usually occurs in four-sided prisms, terminated by dihedral summits; and not unfrequently the two acute edges, or all the four, are truncated. Crystals middle-sized and small. Internal lustre 3, 2, pearly. Fracture sometimes broad radiated, sometimes foliated; both streaked; the latter appears to have a twofold longitudinally intersecting cleavage. Cross fracture uneven. Fragments usually indeterminate; sometimes somewhat cubical. The massive variety is in granular distinct concretions. Transparency 2; of the crystals 3. Semihard. Frangibility 4. Moderately heavy.

Subspecies 3. *Glassy Tremolite.* Colours yellowish, reddish, greyish, and greenish white. Massive and crystallized. Internal lustre 3; passing to 2, pearly. Fracture very narrow radiated. Has parallel oblique cross rents, like the shorlite. Fragments usually splin-

Actinolite Family.

tery. Composed of thin prismatic distinct concretions, which are collected into thick ones. Transparency 2. Frangibility 6. Brittle. Melts before the blow-pipe into a white cellular scoria.

Sp. 4. *Antophyllite* *.

This mineral was first observed at Kongsberg in Norway, and described by Schumacher.

Colour light hair brown, passing into clove brown. Massive. It occurs also in thin flat six-sided prisms, longitudinally streaked, and wanting the extremity. Lustre 4, adamantine. Fracture straight fibrous. Fragments approaching to four-sided prisms. In granular distinct concretions. Transparency of the crystals 4; of the massive 1. Streak white. Semihard in a high degree. Remarkably brittle. Specific gravity 3·156. Powder white with a shade of yellow. When exposed in a crucible to the temperature of 32° Wedgewood it becomes opaque and dark clove brown; but its other qualities remain unaltered. Infusible before the blow-pipe alone, but with borax it melts into a grass green transparent bead. With microcosmic salt it melts into an oil green bead. With fixed alkali it melts readily.

Sp. 5. *Cyanite* †.

Sappare of Saussure—*Disthene* of Hauy.

This stone was first described by Mr Saussure the son, who gave it the name of *sappare* ‡. It is common-

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* Karsten and John, Gehlen's *Jour.* Second series. 2. 496. De-la Metherie. *Jour. de Phys.* lxiv, 356.

† Kirwan, i. 209.—Sage, *Jour. de Phys.* xxxv. 39.—Hauy, iii. 220.—Brochant, i. 501.—Jameson, i. 451.

‡ *Jour. de Phys.* xxxiv. 213.

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ly found in talc and mica slate. The primitive form of its crystals is a four-sided oblique prism, whose sides are inclined at an angle of 103°. The base forms with one side of the prism an angle of 103°; with another, an angle of 77°. It is sometimes crystallized in six-sided prisms *.

Colour various shades of blue; as, smalt, berlin, sky; also milk white, bluish grey, and pearl grey. Some specimens entirely blue, others only spotted with it. Massive and crystallized. Internal lustre 3, 4, pearly. Fracture very broad, diverging, promiscuous radiated; passes sometimes into curve foliated. Fracture of the crystals foliated with a threefold cleavage. Fragments slaty, splintery, wedge-shaped, and sometimes imperfect rhomboidal. In wedge-shaped distinct concretions. Transparency 2, 4. Refracts singly. Slightly flexible. Hardness 6 to 8. Approaching sectile. Feels somewhat greasy. Specific gravity from 3·517 to 3·622. Infusible before the blow-pipe.

Sp. 6. *Sahlite* †.

Malacolite of Abilgaard and Hauy.

This mineral was first observed in the silver mine of Sahla in Westermannia; hence the name. Afterwards it was found in Norway.

Colour light greenish grey. Massive. Internal lustre 3, 4. Principal fracture foliated; cleavage threefold. Fragments frequently rhomboidal. Composed

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* Hauy, *Jour. de Min.* No. xxviii. 282.

† Hauy, iv. 379.—Brochant, ii. 518.—Jameson, ii. 555.—Bournon, *Jour. de Min.* No. lxxiv. p. 108.

of very coarse granular distinct concretions. Transparency 1. Semihard. Brittle. Frangibility 4. Specific gravity from 3·2368 to 3·2307 *. Melts before the blow-pipe into a transparent glass. Hauy has shown that in its structure it bears a striking resemblance to augite.

Sp. 7. *Schalstone* †.

Tafelspath.

This mineral has been hitherto found only in the Bannat of Temeswar. Colour greyish white, passes into greenish and yellowish white, and reddish white. Massive. Lustre of the principal fracture 3, pearly. Principal fracture foliated, with a slight tendency to splintery and coarse fibrous. Cleavage single. In straight thin lamellar distinct concretions, collected into large brown prismatic distinct concretions. Transparency 2. Semihard. Brittle. Frangibility 4. Weight moderate.

The following Table exhibits a view of the constituents of such of the preceding species as have been analysed:

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* Hauy and Dandrada.

† Jameson, i. 519.—Klaproth, iii. 289.

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Constituents.

	Actinolite.	Smaragdite.	Tremolite.						Antophyllite.	Cyanite.		Sahlite.	Schalstone
	*	†	‡	§	‖	‖	‖	‖	¶	**	††	‡‡	§§
Silica	50	50	65	51·5	35·5	28·4	41	50	62·66	30	38·8	53	50
Alumina	0·75	11		0·5					13·33	55	55·5	3	
Lime	9·75	13	18	32	26·5	30·6	15	18	3·33	2	0·5	20	45
Magnesia	19·25	6	10·33		16·5	18	15·25	25	4	2		19	
Soda				8·5									
Potash	0·5												
Oxide of iron	11	5·5	0·16	0·5					12	6	2·75		
Oxide of mang.	0·5								3·25			4	
Ox. of chrom.	3	7·5											
Ox. of copper		1·5											
Carbonic acid }				5	23	23	23	5					
Water }	5		6·5								0·75		
Loss	0·25	5·5	0·01	2			5·75	2	1·43	5	1·7	1	5
	100	100	100	100	101·5	100	100	100	100	100	100	100	100

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* Laugier, *Ann. de Mus. d'Hist. Nat.* v. 79. † Vauquelin, *Ann. de Chim.* xxx. 106. ‡ Klaproth, Crell's *Annals*, 1790, i. 54. § Kennedy, *Phil. Mag.* xiv. 315. ‖ Laugier, Gehlen's *Jour.* Second series, ii. 46. ¶ John, Ibid. 499. ** Saussure, junior, *Jour. de Phys.* 1793, ii. 13. †† Laugier, Gehlen's *Jour.* iv. 535. ‡‡ Vauquelin, Hauy, iv. 382. §§ Klaproth, iii. 291.

Gadolinite Family.

XX. Gadolinite Family.

Though the mineral called gadolinite is arranged by Werner among the ores of iron, yet as it is almost the only mineral known to contain yttria, it may be worth while to insert the description of it here.

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 *Gadolinite*, because Gadolin was the chemist who first ascertained its composition. Colour velvet black, passing sometimes to brown. Massive. Lustre 3, glassy. Fracture conchoidal. Hardness 10. Scratches quartz. Opaque. Brittle. Specific gravity 4·0497. Gelatinizes with hot diluted nitric acid. Before the blow-pipe decrepitates, and assumes a whitish red colour, but does not melt. With borax it melts into a topaz-yellow glass †. Its constituents are as follows:

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* Hauy, iii. 141.—Brochant, ii. 512.—Klaproth, iii. 52.—Jameson, ii. 570.

† Mr Thomas Allan among some minerals from Greenland recognised one, which appears to be a species of gadolinite, though it differs considerably from the mineral described in the text Colour pitch black. Massive, and sometimes in fragments of rhomboidal prisms, with angles of 120° and 60°. Lustre 2, resinous. Fracture uneven Semihard, does not scratch quartz. Opaque. Brittle. Specific gravity 3·4802. Gelatinizes with nitric acid. Frothes before the blow-pipe and melts imperfectly into a brown scoria. With borax melts into a black glass. *Trans. Edin.* vi. 345.

Constituents.

	*	†	‡
Yttria	47·5	35·0	59·75
Silica	25·0	25·5	21·25
Lime		2·0	
Alumina	4·5		0·50
Oxide of iron	18·0	25·0	18·00
Oxide of manganese		2·0	
Water		10·5	
Loss	5·0		0·50
	100	100	100

ORDER II. SALINE STONES.

UNDER this Order are comprehended all the minerals which have an earthy basis combined with an acid. The minerals belonging to it are of course salts, and as such have been described in a former part of this Work: But as they occur native in states which cannot always be imitated by art, it will be necessary to take a view of them as they are found in the earth. They naturally divide themselves into five genera, as only five earths have hitherto been discovered native in combination with an acid. These earths are, lime, barytes, strontian, magnesia, and alumina. The species belonging to each genus might be arranged according to their external characters; but as their constituents afford well marked and important characteristics, it will answer our purpose better to arrange each mineral ac-

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* Ekeberg, Crell's *Annals*, 1799, ii. 67.

† Vauquelin, *Ann. de Chim.* xxxvi. 152.

‡ Klaproth, *Beitrage*, iii. 65.

Saline Stones.

cording to its composition. The following Table exhibits a view of the different saline stones arranged in that manner*:

Table of species,

I. GENUS. CALCAREOUS SALTS.

- I. *Family of Carbonates*
  - *a.* Nearly pure
    - Rock-milk
    - Chalk
    - Lime-stone
    - Calctuff
    - Schaumearth
    - Slate spar
    - Arragonite
  - *b.* Combined with a foreign body
    - Brown spar
    - Dolomite
    - Rhomb spar, or bitter spar
    - Swine-stone
    - Marl
    - Bituminous marl slate
- II. *Family of Phosphates*
  - Appatite
  - Asparagus stone
  - Phosphorite
- III. *Family of Fluates*
  - Fluate of lime
- IV. *Family of Sulphates*
  - Gypsum
  - Selenite

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* See Jameson's *Mineralogy*, ii. 591.

Cube spar
Anhydrite
V. *Family of Borates*
Datholite
II. GENUS. BARYTIC SALTS
Carbonate
Sulphate
III. GENUS. STRONTIAN SALTS
Carbonate
Sulphate
IV. GENUS. MAGNESIAN SALTS
Sulphate
Carbonate
Borate
V. GENUS. ALUMINOUS SALTS
Alum
Mellate
Chryolite

The minerals belonging to this Order are distinguished without much difficulty from the last. Almost all of them are insoluble in water; but soluble in nitric acid or in hot sulphuric acid. Most of them melt before the blow-pipe. Their specific gravity varies; but it is often above 3·5 when the mineral is too soft to scratch glass. None of them have the metallic lustre.

GENUS I. CALCAREOUS SALTS.

THE existence of pure uncombined lime in a nativ 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. Monne 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, lately engaged in collecting the minerals about Bath, found it, though not in any great quantity. But as the pure lime in these specimens is mixed with other bodies, it can scarcely with propriety be considered as a distinct mineral.

This genus comprehends all the combinations of lime with an acid that occur in the mineral kingdom.

I. Family of Carbonates.

Family of Carbonates.

No other mineral can be compared with carbonate 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 lime-stone, chalk, marble, spar, it does not constitute a greater or smaller part of the mineral riches.

This salt is often pure or nearly so; but it is frequently also either chemically combined, or at least intimately mixed with a considerable proportion of some other substance which changes its appearance and its properties. The first seven species of this family enumerated in the preceding table are nearly pure car-

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* Monnet's *Mineralogy*, p. 515.

† *On Bath Waters*, p. 156.

Book III. Chap. II.

bonates; but the last six are compounds, or intimate mixtures of carbonate of lime with some other body.

Sp. 1. *Rock-milk* *.

Agaric mineral—Mountain-milk.

Found in the fissures and holes of lime-stone mountains, chiefly in Switzerland, and is supposed to be deposited by the rain water that filters through the rocks. Colour yellowish white, sometimes snow and greyish white. Composed of dusty particles without lustre, which cohere but weakly. Feels fine but meagre. Stains very much. Does not adhere to the tongue. Nearly floats on water.

Sp. 2. *Chalk* †.

This mineral forms a peculiar formation, and abounds particularly in the south of England and north of France. Colour yellowish white, sometimes snow and greyish white. Lustre 0. Opaque. Hardness 3 to 4. Specific gravity from 2·315 to 2·657. Fracture fine earthy. Fragments blunt edged. Adheres slightly to the tongue. Feels meagre and rough. Stains the fingers, and marks. Sectile.

Sp. 3. *Lime-Stone* ‡.

This mineral occurs in great abundance and in a great variety of situations, and differs in its appearance according to its situation. Hence it has been divided

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* Kirwan, i. 76.—Brochant, i. 519.—Jameson, i. 471.

† Kirwan, i. 77.—Brochant, i. 521.—Jameson, i. 473.

‡ Kirwan, i. 82.—Brochant, i. 523.—Hauy, ii. 127.—Jameson, i. 476.

by Werner into four subspecies, distinguished chiefly by their fracture and their geognostic position.

Family of Carbonates.

Subspecies 1. *Compact Lime-Stone.* This mineral is confined almost exclusively to the floetz and coal formations. It is usually massive, and never crystallized. Its texture is compact, its fracture splintery, and it has no internal lustre. It is often used for building, and for burning to lime. There are two varieties of it; namely, *common* compact lime-stone and *roe-stone.* The first of which is much more abundant than the second.

1. Common. Colour various shades of grey; namely, yellowish, bluish, ash, and smoke grey; greyish black; yellowish brown, ochre yellow; also blood, flesh, and peach blossom red. Often spotted and veined. Fracture small fine splintery, passing sometimes into large flat conchoidal, and into uneven. Fragments more or less sharp-edged. Transparency 1. Hardness 6 to 8. Brittle. Frangibility 4. Specific gravity 2·6 to 2·7.

2. Roe-Stone. Colour hair and chesnut brown; but from the quantity of marl which it contains, it appears yellowish and ash grey. Fracture fine splintery, but not easily observed. Fragments very blunt-edged. Composed of small globular distinct concretions; each globule is composed of concentric lamellar concretions. Transparency 0, 1. Hardness 6 to 8. Brittle. Frangibility 6.

Subspecies 2. *Foliated Lime-Stone.* This subspecies is distinguished from the preceding by its foliated fracture. All the calcareous crystals belong to it, except one or two, which are peculiar to the arragonite. There are two kinds of it, easily distinguished from each other by the shape of the fragments; the fragments of the first kind being indeterminate, while those of the second are always rhomboidal. The first kind is called *granular foliated*, from the granular distinct concretions of which it is composed; the second *calcareous spar*, from the shape of the fragments.

1. Granular foliated. This kind belongs almost exclusively to the primitive and transition mountains, where it occurs in great abundance. The *marbles* used in sculpture, and many of those employed in architecture, belong to it. It is never found crystallized.

Colour various shades of white; namely, snow, yellowish, greyish, greenish, reddish; bluish, greenish ash, and smoke grey; greyish black; pearl grey, flesh red; cream yellow; siskin and olive green. Sometimes spotted and clouded. Internal lustre from 3 to 1, between pearly and vitreous. Fracture foliated sometimes from the fineness of the grains appears splintery. Fragments blunt-edged. Mostly in granular distinct concretions; sometimes they are so fine that the mineral passes into compact. Transparency 2. Hardness 6 to 8. Brittle. Frangibility 5. Specific gravity from 2·7 to 2·84.

2. Calcareous Spar. This kind is found in veins; and it occurs in every formation, being indeed the most generally distributed of all minerals. It occurs massive and in different particular shapes, but more frequently crystallized. The primitive form of its crystals is a parallelopiped, whose sides are rhombs, with angles of 78° 30′ and 101° 30′. Its integrant molecules have the same form. The varieties of its crystals amount to 616. For a description and figure of which

Family of Carbonates.

the reader is referred to Romé de Lisle *, Hauy †, and Bournon ‡.

Werner has given a very luminous view of the varieties of these crystals, by supposing three fundamental figures ; namely, the six-sided pyramid, the six-sided prism, and the three-sided prism, and forming all the other crystals by truncations of these §.

Colours greyish, yellowish, greenish, and reddish white ; olive, asparagus, pistachio, and leek green ; greenish grey ; sometimes yellow, rose red, and pale violet blue, but very seldom. Internal lustre from 4 to 2, vitreous. Fracture perfect foliated ; cleavage threefold. Fragments rhomboidal. Massive. Varieties occur in granular distinct concretions, and in prismatic and wedge-shaped concretions which are oblique longitudinally streaked. Transparency of the massive 2 to 4 ; of the crystals 4, 3. Refracts strongly double. Hardness 6 to 8. Brittle. Frangibility 5. Specific gravity 2·693 to 2·718. Many varieties become phosphorescent on hot coals.

Subspecies 3. *Fibrous Lime-Stone.* This subspecies is by no means so universally distributed as the preceding. It is divided into two kinds, the *common fibrous* and *calcsinter.* The first occurs in small veins ; and the second consists chiefly of stalactites, formed by the filtration and evaporation of water impregnated with carbonate of lime. None of them are crystallized.

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* *Crystallog.* i. 497. † *Essai d'une Theorie*, &c. p. 75.—*Jour. de Phys.* 1793, August, p. 11. and *Miner.* ii. 130.—*Jour. de Hist. Nat.* 1792, February, p. 148.—*Ann. de Chim.* xvii. 249, &c.—*Jour. de Min.* No xxviii. 304. ‡ *Traité de Mineralogie*, Toms. i. ii. and iii.

§ See Jameson's *Min.* i. 489.

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1. Common Fibrous. Colours greyish, reddish, and yellowish white. Massive. Lustre 2, 3, pearly. Fracture coarse and delicate, straight and parallel fibrous. Fragments splintery. Transparency 2. Hardness 6 to 8. In other respects similar to the last subspecies. The *satin spar* belongs to this kind.

2. Calcsinter. Colours snow, greyish, greenish, and yellowish white; honey yellow, yellowish brown; siskin, pistachio, asparagus, mountain, and verdegris green; the last passes into sky blue; flesh and peach blossom red, reddish brown: But the red and green varieties are rare, and owe their colour to metals. Massive and in particular shapes. Internal lustre 1, passing into 2, pearly. Fracture straight scopiform and stellular fibrous. Fragments usually indeterminate; sometimes splintery and wedge-shaped. Usually in curved lamellar distinct concretions. Transparency 2, sometimes 3. Hardness 6, 7. Brittle. Frangibility 5.

Subspecies 4. *Pea-Stone.* This mineral is found in the vicinity of the hot springs at Carlsbad in Bohemia. It has the form of round masses composed of concentric layers, and containing each a grain of sand in their centre. Colour yellowish white, sometimes snow white and yellowish brown. The round bodies are collected together like a bunch of grapes. Lustre 0. Frangibility 6. Transparency 0 or 1. Hardness 6 to 7. Moderately heavy. Fracture even.

Sp. 4. *Calctuff*[*].

This mineral occurs in alluvial land, and appears to

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[*] Jameson, i. 531.

be daily formed by means of calcareous springs. Colour yellowish grey. Generally marked with impressions of reeds, grass, or moss. Internal lustre 0, 1. Fracture between fine-grained uneven and earthy; sometimes inclines a little to fibrous or foliated. Fragments blunt-edged. Opaque, or transparency 1. Soft. Somewhat sectile. Frangibility 4. Light. Almost swims in water.

Sp. 5. *Schaumearth* *.

Silvery chalk of Kirwan.

This mineral occurs in cavities of floetz lime-stone. It is found near Gera, in Thuringia, and in the north of Ireland. Colour light yellowish (nearly silver) white. Massive and disseminated, or in fine scaly particles. Lustre between 3 and 2. Between semimetallic and pearly. Fracture curve foliated. Cleavage single; passes into scaly. Fragments blunt-edged. In granular distinct concretions. Opaque. Soils a little. Very soft. Sectile. Friable. Feels fine. Creaks a little. Light.

Sp. 6. *Slate Spar, or Schieferspath* †.

Argentine of Kirwan.

This mineral occurs in beds in primitive mountains, and has been found in Norway, Saxony, and Cornwall.

Colour milk, greenish, and reddish white. Massive. Lustre 3, 2, pearly. Texture curve foliated. Frag-

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* Kirwan, i. 78.—Brochant, i. 557.—Jameson, i. 505.

† Kirwan, i. 105.—Brochant, i. 558.—Jameson, i. 508.

ments slaty. Brittle. Transparency 2. May be scratched by the nail. Specific gravity 2·740. Between sectile and brittle. Frangibility 4.

Sp. 7. *Arragonite*[*].

This mineral was first found in Arragon imbedded in gypsum; afterwards in the Pyrenees and at Saltzburgh. Colour greenish and pearl grey; in the middle often violet and green. Always crystallized in regular six-sided prisms; or having two opposite faces larger. Longitudinally striated. Lustre 2, glassy. Fracture between imperfect foliated and fibrous. Colour arranged in the direction of the fibres; the longitudinal fibres green, the transverse violet blue. Cleavage double; one parallel to the axis, another forming with the first an angle of 116½°. Transparency 2. Refracts doubly. Scratches calcareous spar. Brittle. Specific gravity 2·9468.

The following Table exhibits the constituents of the preceding species, which may be considered as nearly pure carbonates, as far as analyses have hitherto ascertained them.

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[*] Kirwan, i. 87.—Brochant, i. 576.—Hauy, iv. 337.—Jameson, i. 533.

Family of Carbonates.

Constituents.

	Chalk.	Common Compact Lime-Stone.						Granular Foliated.	Calcareous Spar.		Calcsin-ter.	Schaum-earth.	Slate Spar.		Arrago-nite.
	*	†	†	†	†	†	‡	§	‖	¶	**	††	‡‡	§§	‖‖
Lime	56·5	53	49·50	48	47·25	49·25	33·41	56·5	55·5	56·5	56	51·5	54·7	55	54·5
Carb. acid	43	42·5	40	38	38·25	35	42	43	44	43·0	43	39	43·3	41·7	41·5
Water	0·5	1·63	1·13	1	2·25			0·5	0·5	0·5	1	1	0·5		3·5
Silica		1·12	5·25	7	5·75	8·75	10·25					5·7	·05		
Alumina		1	2·75	4	3·75	2·5									
Magnesia							9·43								
Ox. of Iron		0·75	1·37	2	Trace	2·75	2·25					3·3	·80		
Ox. of Man.					2·75	Trace	1·25							3	
Loss						1·75	1·41						·65	0·3	0·5
	100	100	100	100	100	100	100	100	100	100	100	100·5	100	100	100

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* Bucholz, Gehlen's *Jour.* iv. 416. It gave traces also of alumina and iron, and of muriatic acid.

† Simon, Ibid. iv. 426. ‡ Bucholz, Gehlen's *Jour.* Second Series, ii. 18. The variety analysed is known in Germany by the name of *Mehl bass.* § Bucholz, Gehlen's *Jour.* iv. 414. ‖ Philips, *Phil. Mag.* xiv. 290. ¶ Bucholz, Gehlen's *Jour.* iv. 412. Both this and the preceding analysis were made on pure specimens of *Iceland Crystal.* ** Bucholz, Ibid. p. 425. †† Id. p. 422. ‡‡ Philips, *Phil. Mag.* xiv. 292. §§ Bucholz, Gehlen's *Jour.* iv 419. ‖‖ Id. Ibid. iii. 80. This analysis coincides with hea nalyses of this mineral previously made by Klaproth and Thenard.

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Sp. 8. *Brown Spar**.

Spath perlé—Sidero-calcite.

This mineral occurs in veins, and is usually accompanied by calcareous spar and sparry iron ore. Principal colours white and red: namely, greyish, yellowish, reddish white; flesh, rose, and brownish red; brown. Some varieties approach pearl grey, others black. Sometimes spotted. Massive, globular, and crystallized. Crystals the same as those of calcareous spar. The following have been observed: a flat and an acute double three-sided pyramid, an oblique six-sided pyramid; also in lenses and rhombs. External lustre 3; internal from 3 to 4; sometimes 2, pearly. Fracture sometimes straight foliated, more commonly spherical curve foliated. Threefold cleavage, like calcareous spar. Fragments rhomboidal. In granular distinct concretions of all sizes, and in straight lamellar concretions. Transparency 2, 1; of the crystals 3. Scratches calcareous spar. Frangibility 2. Specific gravity 2·837. Effervesces slowly in acids.

A variety of this mineral, hitherto found only in Hungary and Transylvania, has been distinguished by Werner as a subspecies, under the name of *fibrous brown spar*. Colour flesh red. Massive. Lustre 2. Fracture straight and diverging fibrous. Fragments splintery and wedge-shaped. In other characters it resembles common brown spar.

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* Kirwan, i. 105.—Brochant, i. 563.—Hauy, ii. 175.—Jameson, i. 510.

Sp. 9. *Dolomite* *.

This mineral was first particularly noticed by Dolomieu, on account of its superior harshness to granular limestone, and the slowness with which it effervesced in acids. It was long considered as a variety of common limestone; from which, however, it differs essentially in its composition, as was first shown by Mr Tennant. It occurs abundantly at St Gothard, in the Appenines and other primitive mountains.

Colour greyish white, sometimes inclining to yellowish white. Massive. Internal lustre 2. Fracture seems foliated, but is not easily discovered, on account of the smallness of the distinct concretions. Fragments blunt-edged. In fine granular distinct concretions. Transparency 1. Semihard. Frangibility 2. Feels harsh and meagre. Rather heavier than limestone. Specific gravity 2·835 †. Does not phosphoresce when heated.

Sp. 10. *Rhomb Spar*, or *Bitter Spar* ‡.—*Muricalcite*.

This mineral occurs in chlorite and similar rocks in Switzerland, the Tyrol, Sweden, Scotland, &c. and is always crystallized. Its constituents indicate that it bears the same relation to the preceding species that calcareous spar does to granular limestone.

Colours greyish and yellowish white, yellowish grey. Always in middle-sized rhombs, similar to the primi-

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* Kirwan, i. 111.—Hauy, ii. 173.—Jameson, ii. 606.—Klaproth, Gehlen's *Jour*. ii. 116.

† Klaproth, Gehlen's *Jour*. ii. 125.

‡ Kirwan, i. 92.—Brochant, i. 560.—Hauy, ii. 187.—Jameson, i. 516.

tive crystal of calcareous spar. Lustre 4, between vitreous and pearly. Fracture straight foliated, with a threefold cleavage; cross fracture uneven and imperfect flat conchoidal. Transparency between 2 and 3. Scratches calcareous spar. Brittle. Frangibility 5. Specific gravity 2·480.

Sp. 11. *Swinestone* [*].

This mineral occurs chiefly in beds, alternating with the oldest floetz gypsum, and is found in considerable quantity in the district of Mansfeld, in Thuringia. Colour wood brown, passing into yellowish brown and brownish black. Massive. Internal lustre from 0 to 1. Fracture commonly earthy, and very small splintery; sometimes shows a tendency to slaty. The black variety has a conchoidal fracture. Fragments indeterminate and slaty. Sometimes in very small grained distinct concretions. Transparency 1, 0. Hardness 6, 7. Frangibility 5. Specific gravity 2·712. When rubbed, emits an urinous smell.

Sp. 12. *Marl* [†].

A mixture of carbonate of lime and clay, in which the carbonate considerably exceeds the other ingredient, is in common language called *marl*. Mr Kirwan has divided marls into two varieties: 1. Those which contain more silica than alumina; 2. Those which contain more alumina than silica. He has called the first

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[*] Kirwan, i. 89.—Brochant, i. 567.—Hauy, ii. 189.—Jameson, i. 521.

[†] Kirwan, i. 94.—Brochant, i. 569.—Hauy, iv. 455.—Jameson, i. 524.

Family of Carbonates.

of these *siliceous*, the second *argillaceous* marls. Attention should be paid to this distinction when marls are used as a manure. Werner divides marls into two subspecies, *earthy* and *indurated* marl.

Subspecies 1. *Earthy Marl.* Colour yellowish grey. Composed of dull dusty particles. Feels rather meagre. Soils a little. Sometimes loose, sometimes cohering.

Subspecies 2. *Indurated Marl.* Occurs in the floetz lime and coal formations. Colour grey, sometimes yellowish grey. Massive. Lustre 0; sometimes 1, from foreign particles. Fracture earthy; sometimes splintery, or imperfect slaty. Fragments indeterminate, partly slaty. Transparency 0 or 1. Yields to the nail. Not particularly brittle. Frangibility 4. Specific gravity from 1·6 to 2·877. Melts before the blow-pipe into a greyish black glass. Falls in the air. Passes into limestone and indurated clay.

Sp. 13. *Bituminous Marl Slate**.

This mineral occurs in beds along with the oldest floetz limestone. Often intermixed with ores of copper. Contains a great number of petrefied fish. Colour greyish or brownish black. Massive. Fracture curved or straight slaty. Lustre 1, 2, 3. Fragments slaty. Opaque. Hardness 4. Feels soft. Frangibility 4. Sectile. Moderately heavy. Streak shining. Effervesces with acids. Burns before the blow-pipe, leaving black scoriæ.

THE six preceding species may be considered as combinations, or mechanical mixtures, of carbonate of lime

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* Kirwan, i. 103.—Brochant, ii. 574.—Jameson, i. 529.

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with some other substance. The following Table exhibits a view of their constituents, as far as ascertained.

1. Brown spar is carbonate of lime combined with the oxides of iron and manganese.

2. Dolomite and rhomb spar, carbonate of lime combined with carbonate of magnesia.

3. Swinestone, supposed to be carbonate of lime combined with sulphureted hydrogen.

4. Marls, mixtures of carbonate of lime with clay.

	Brown Spar.		Dolomite.					Rhomb Spar.				
	*	†	‡	‡	‡	‡	†	§	§	‖	¶	**
Carb. of lime	38	51·5	52	59	65	42	51·5	52	73	53	60	68
Carb. of magn.		32	46·5	40·5	3	48	48	45	25	42·5	36·5	25·5
Carb. of iron		7·5										1
Carb. of mangan		2										
Oxide of iron	38		·5			5·2		3	2·25	3	4	
Ox. of mangan.	24		·25									
Clay												2
Water		5										2
Loss		2	·75	0·5			0·5			1·5		1·5
	100	100	100	100	100	100·2	100	100	100·25	100	100·5	100

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* Bergman, ii. 228. The manganese he states as combined with carbonic acid.

† Klaproth, *Beitrage*, iv. 199. The specimen was from Mexico, and differed in several respects from common brown spar. It was snow white, and composed of long flat thin columns seemingly hexahedral.

‡ Klaproth, Gehlen's *Jour.* ii. 115. The first specimen was from St Gothard, and seems to be the same as that formerly analysed by Saussure with a very different result; the second from the Appenines, near Castelamare, in the state of small sandy particles perceptibly rhomboidal; the third compact, and from the Appenines; the fourth from the Alps; the fifth from an antique marble.

§ Klaproth, *Beitrage*, i. 304. The first specimen from the Tyrol, the second from Sweden.

‖ Ibid. iii. 296. This was the variety of rhomb spar called *Miemite*, of a green colour, and found at Miemo in Tuscany, in flat double three-sided pyramids.

¶ Klaproth, Ibid. p. 297. This mineral has received the name of *prismatic bitter spar* from its figure. Colour green, and crystallized in tetrahedrons. Found at Gotha.

** Klaproth, *Beitrage*, iv. 236. From Hall in the Tyrol.

Family of Phosphates

II. FAMILY OF PHOSPHATES.

THIS family is divided by Werner into three species; but the two first are so intimately connected that it would be better perhaps to consider them only as subspecies.

Sp. 1. *Apatite* *.

This mineral occurs in tin veins, and is found in Cornwall and Germany. Werner first constituted it a new species, and gave it the name which it bears †.

Colours white, green, blue, and red, of various shades: as greyish, reddish, yellowish, and greenish white; mountain, seladon, pistachio, and leek green; rose and flesh red; pearl grey; violet, lavender, and indigo blue; yellowish brown. All the colours rather light. Mostly 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 $\sqrt{2}$ ‡. The six-sided prisms are always low, and sometimes pass into the six-sided table. Lateral edges and angles sometimes terminal, frequently truncated. Lateral faces usually longitudinally streaked; acuminating faces smooth. External lustre 4; internal 3, resinous, approaching vitreous. Fracture imperfect foliated; cleavage fourfold, as in the beryl. Cross fracture uneven, approaching small conchoidal.

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* Kirwan, i. 128.—Brochant, i. 580.—Hauy, ii. 234.—Jameson, i. 536.

† From αϖαταω, because it had been erroneously arranged along with other minerals.

‡ Hauy, *Jour. de Min.* No. xxviii. 310.

The massive in coarse granular concretions. Transparency 4 to 2. Causes single refraction. Hardness 6 to 7; scratched by fluor spar. Brittle. Frangibility 4. Specific gravity between 2·824 and 3·2. Phosphoresces on hot coals.

Sp. 2. *Asparagus Stone* *.

This mineral has hitherto been found only at Caprera in Murcia, a province of Spain. It was this species which Romé de Lisle and the other French chemists considered as a chrysolite.

Colour asparagus green, sometimes passing to greenish white, or pistachio green; sometimes between orange and yellowish brown. Always crystallized in equiangular six-sided prisms, obtusely acuminated by six planes set on the lateral planes; lateral edges truncated. Planes longitudinally streaked, also smooth. Crystals complete. Internal lustre 3, 4, vitreous. Fracture concealed foliated, passing into uneven. Transparency 2, sometimes nearly 4. Semihard, approaching soft. Frangibility 4. Brittle. Specific gravity 3·098. Does not phosphoresce.

Sp. 3. *Phosphorite* †.

This mineral forms great beds in the province of Estremadura. Colour yellowish white; often spotted yellowish grey. Massive. Internal lustre 1, 0. Fracture imperfect curved foliated, inclining to the floriform

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* Brochant, i. 586.—Vauquelin, *Jour. de Min.* No. xxxvii. 19.—Jameson, i. 540.

† Brochant, i. 584.—Bertrand, Pelletier, and Donadei, *Jour. de Phys.* xxxvii. 161.—Jameson, ii. 556.

Family of Phosphates.

foliated; sometimes passes to coarse earthy. Fragments blunt-edged. Tends to thick lamellar distinct concretions. Transparency 1. Soft, approaching semihard. Brittle. Specific gravity 2·814.

There is a substance found at Kobolobanya near Szigeth, in the county of Marmarosch in Hungary. It is an earthy matter which phosphoresces when heated, emitting a pale yellow light. This property induced mineralogists to consider it as a variery of fluate of lime, till Hassenfratz analysed it, and found it to consist chiefly of phosphoric acid and lime*. Hence it was considered as similar to the phosphorite of Estremadura. Pelletier examined it soon after, and again restored it to the place of fluate; having found it a mixture of fluate of lime with silica and alumina, and a little phosphoric acid, muriatic acid, and iron †. Klaproth has lately analysed it, and shown that the original experiments of Hassenfratz were accurate. Of course, it must be considered as approaching the nature of the phosphorite of Estremadura. The result obtained by Klaproth has been inserted in the following Table.

The composition of apatite was first ascertained by Proust: Vauquelin was the first of the French chemists who determined the composition of asparagus-stone. I do not know whether it had been previously analysed in Germany. Proust first determined the composition of phosphorite. A more exact analysis was afterwards made by Pelletier, Bertrand, and Donadei. The following Table exhibits the result of these different experiments:

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[*] *Ann. de Chim*, i. 191.

[†] *Ann. de Chim.* ix. 225.

Constituents.

	Apatite.		Asparagus-Stone.	Phosphorite.	Hungarian Phosphorite.
	*	†	‡	§	‖
Lime	55	53·75	53·32	59	47
Phosph. acid	45	46·25	45·72	34	32·25
Carbonic acid				1	
Muriatic acid				·5	
Fluoric acid				2·5	2·5
Silica				2	0·5
Oxide of iron				1	0·75
Water					1
Quartz and rock mixed					11·5
Loss			·96		4·5
	100	100	100	100	100

III. Family of Fluates.

This family comprehends only one species; namely, *fluor*, which Werner divides into two subspecies. The first is very rare, the second very common.

Subspecies 1. *Compact Fluor*. It is found in veins along with the next subspecies in the Hartz. Colours greyish white and greenish grey; sometimes inclining to blue; sometimes marked with yellow or red spots. Massive. External lustre 0, 1; internal 1, vitreous.

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* Klaproth, *Jour. de Min.* No. xxxvii. p. 26.

† Klaproth, *Beitrage*, iv. 194. The specimen was from Zillerthale. It was massive, of an asparagus green colour, specific gravity 3·190. Principal fracture foliated, cross fracture conchoidal.

‡ Vauquelin, *Jour. de Min.* Ibid.

§ Pelletier, Bertrand, and Donadei, *Jour. de Phys.* xxxvii. 161.

‖ Klaproth, *Beitrage*, iv. 366.

Family of Fluates.

Fracture even. Fragments sharp-edged. Scratches calcareous spar. Brittle. Frangibility 4. Moderately heavy.

Subspecies 2. *Fluor spar*. This mineral occurs in beds in the primitive mountains, also in veins along with tin, lead, and copper.

Colours very numerous, being various shades of blue, green, yellow, white, red, black, and brown. Several frequently occur together. Massive and frequently crystallized. 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 nine. 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[†]. Surface smooth, sometimes drusy. Lustre of the first 4 ; of the second 2. Internal lustre 4, vitreous. Fracture foliated ; cleavage fourfold. Fragments tetrahedral or octahedral. Transparency 2 to 4. Refracts singly. In granular and prismatic distinct concretions. Hardness 8. Brittle. Frangibility 4. Specific gravity 3·0943 to 3·1911. Its powder thrown upon hot coals emits a bluish or greenish light. Two pieces of it rubbed in the dark phosphoresce. It decrepitates when heated. Before the blow-pipe it melts into a transparent glass[‡].

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[*] Hauy, *Jour. de Min.* No. xxxviii. 325.

[†] Ibid. and *Min.* ii. 249.

[‡] Hauy, *Jour. de Min.* No. xxviii. 325.

It admits of a polish, and is often formed into vases and other ornaments.

The composition of pure fluate of lime is as follows;

	*	†	‡
Lime	32·25	32·66	35
Fluoric acid	67·75	67·34	65
Total	100	100	100

IV. Family of Sulphates.

Werner divides this family into four species; namely, *gypsum*, *selenite*, *cube-spar*, and *anhydrite*; but it appears, from late observations, that the two last run into each other, and should therefore be only subspecies.

Sp. 1. *Gypsum* ||.

This mineral, which abounds in nature, occurs in four different situations in beds; namely, in the primitive, the transition, the oldest, and the second floetz lime-stone. It has been divided into four subspecies.

Subspecies 1. *Gypsum Earth.* Rare. Found in the cavities of the other subspecies, and is supposed to be deposited from water filtering through them. Colour yellowish white, sometimes nearly snow white. Of the consistence of meal. Lustre 0. Opaque. Scarcely sinks in water. Is not gritty between the teeth. Feels

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* Klaproth Beitrage 4. 366.

† By my analysis.

‡ Richter, as quoted by Klaproth, *Beitrage*, iv. 361.

|| Kirwan, i. 120.—Brochant, i. 601.—Hauy, ii. 266.—Jameson, i. 556.

dry and meagre. When heated below redness, it becomes of a dazzling white.

Subspecies 2. *Compact Gypsum.* This and the subsequent species lie over the oldest floetz lime-stone. Colour ash grey. Massive. Internal lustre 0, 1. Fracture even; passing into fine splintery. Fragments blunt-edged. Transparency 1. Hardness 4. Specific gravity about 2·3. Sectile. Frangibility 3.

Subspecies 3. *Foliated Gypsum.* This mineral bears some resemblance to granular lime-stone, but is much softer. Colours white, grey, and red; sometimes yellow, brown, black, of various shades. Often spotted. Massive, and sometimes in conical lenses imbedded in clay. Internal lustre from 3 to 2; between pearly and vitreous. Fracture perfect (somewhat curved) foliated; single cleavage; sometimes diverging radiated. Fragments indeterminate, blunt-edged. In granular distinct concretions; the radiated in prismatic concretions. Transparency 2. Hardness 4. Rather sectile. Frangibility 3. Specific gravity from 2·274 to 2·310.

Subspecies 4. *Fibrous Gypsum.* This mineral lies over the variegated sand-stone, and characterizes that formation. Colours various shades of white, grey, and red. Massive and dentiform. Internal lustre 2; sometimes 3, 4, pearly. Fracture parallel fibrous; sometimes bordering on radiated. Fragments mostly splintery. Transparency 3, 2. Hardness 4. Rather sectile. Frangibility 5.

Sp. 2. *Selenite.*

This species includes all the crystallized specimens of sulphate of lime. Foliated gypsum bears the same relation to it that granular lime-stone does to calcareous spar. It occurs in the oldest gypsum formation, and sometimes in veins. Fine specimens are found in Oxfordshire.

Principal colour snow white; also yellowish and greyish white, and various shades of grey, yellow, and brown. Massive and often crystallized. The primitive form of its crystals is a four-sided prism, whose bases are oblique parallelograms, with angles of 113° 7′ 48″ and 66° 52′ 12″. It occurs crystallized in six-sided prisms, terminated by two-sided or four-sided summits. For a description and figure of its varieties, the reader is referred to Romé de Lisle * and Hauy †.

Internal lustre 3, 4, pearly. Fracture perfect foliated, with one perfect and two imperfect cleavages. Fragments rhomboidal; sometimes in granular distinct concretions. Transparency 4. Refracts doubly. Hardness 4. Sectile. Easily split into plates, which are somewhat flexible. Frangibility 3. Specific gravity 2·322.

Sp. 3. *Cube-Spar* ‡.

Anhydrous sulphate of lime of Hauy—*Muriacite.*

This mineral seems to have been first noticed by the Abbé Poda, who called it *muriacite*, on the supposition that it is a combination of lime and muriatic acid. Fichtel gave an account of it in 1794. Klaproth soon after analysed it; but mineralogists did not pay much attention to it, till Hauy pointed out its characters in the

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* *Crystallog.* i. 144. † *Mineralogie*, ii. 270.

‡ Hauy, iv. 348.—Bournon, *Jour. de Min.* No. lxxvii. p. 345.—Jameson, i. 571.—Klaproth, Gehlen's *Jour.* ii. 357.

Family of Sulphates.

fourth volume of his Mineralogy. It was soon after described by Bournon. It was first found in the salt pits at Hall in the Tyrol, afterwards in the canton of Berne, at Volpino in Sweden, &c.

Colour milk white, which sometimes passes into greyish, yellowish, and reddish white, approaching pearl grey. Massive, and crystallized in four-sided prisms, approaching the cube, but having two of the opposite lateral faces much broader than the other two; sometimes the lateral edges are truncated, which converts the crystal into an eight-sided prism; sometimes the truncations are so great as to destroy the narrow lateral faces, and then the crystal becomes a six-sided prism *. External lustre of the broad faces of the crystal 4, and pearly; of the narrow 2. Internal 3, 4, pearly. Fracture perfect foliated. Cleavage threefold and rectangular. Fragments cubical. In granular and lamellar distinct concretions. Transparency 2. Scratches calcareous spar. Frangibility 6. Specific gravity from 2·850 to 2·964 †.

Sp. 4. *Anhydrite* ‡.

This mineral has hitherto been found only at Sulz on the Neckar. It is obviously only a variety of the preceding. Colour smalt blue, which passes into milk white. Massive. Fracture partly imperfect curved foliated, which sometimes passes into radiated; partly splintery. Lustre 3, 2, pearly. Fragments indeterminate and sharp-edged. Shows a tendency to fine gra-

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* Bournon. † Bournon, Hauy, and Klaproth.

‡ Jameson, ii. 557.—Klaproth, Gehlen's *Jour.* ii. 357.

nular distinct concretions. Transparency 2. Semihard. Not particularly brittle. Frangibility 3. Specific gravity 2·940 ‖‖.

The following Table exhibits a view of the constituents of the preceding species, resulting from the most accurate analyses of them hitherto published :

Constituents.

	Fibrous Gypsum.	Selenite.	Cube-spar.					Anhydrite.
	*	†	‡	§	‖	¶	¶	**
Sulph. acid	43·5	43 9	60	58	57	56·5	55	57
Lime	33	33	40	42	42	42·0	41·75	42
Water	21	21						
Oxide of iron								0·1
Silica								0·25
Muriatic acid					0·1			
Common salt						0·25	1	
Loss	2·5	2·1			0·9	1·25	2.25	0·65
	100	100	100	100	100	100	100	100

V. Family of Borates.

To this family there belongs only a single species ; namely, the *datholite*, a newly discovered mineral.

‖‖ Klaproth.

* Bucholz, Gehlen's *Jour.* v. 160.

† Bucholz, Ibid. p. 158.

‡ Vauquelin, Hauy, iv 349.

§ Chenevix, *Jour. de Min.* xiii. 419. He states the proportion of sulphuric acid at 44·88 ; but he obtained 187 parts of sulphate of barytes. Now if we reckon 31 *per cent.* for the proportion of sulphuric acid in this salt, we obtain 58 for the quantity in 187 parts of sulphate.

‖ Klaproth, Gehlen's *Jour.* ii. 360.

¶ Klaproth, *Beitrage*, iv. 231. The first specimen from Bochnia, the second from Hall in the Tyrol.

** Klaproth, Gehlen's *Jour.* ii. 359.

Sp. 1. *Datholite* *.

This mineral has been recently discovered by Esmark, near Arendal in Norway. For the discovery of its composition we are indebted to Klaproth.

Colour greyish and greenish white; sometimes mountain green. Massive, and crystallized in flat rectangular four-sided prisms, having their angles truncated. Crystals small. External lustre 2; internal 3, between vitreous and resinous. Fracture small imperfect conchoidal. Fragments indeterminate. In large and coarse granular distinct concretions, which have a rough glimmering surface. Semihard in a high degree. Transparency 3, 2 †. Specific gravity 2·980 ‡.

From the analysis of Klaproth, we learn that this mineral is composed of

Silica......	36·5
Lime......	35·5
Boracic acid	24
Water.....	4
	100 with a trace of iron.

GENUS II. SALTS OF BARYTES.

THIS genus comprehends only two species; namely, the *carbonate* and *sulphate* of barytes, the latter of which is much more abundant than the former.

Sp. 1. *Carbonate of Barytes* §.—*Witherite.*

This mineral occurs at Anglesark in Lancashire in

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[*] Klaproth, Gehlen's *Jour.* vi. 107.

[†] See Karsten, Gehlen's *Jour.* vi. 108.

[‡] Klaproth.

[§] Kirwan, i. 134.—Brochant, i. 613.—Hauy, ii. 309.—Jameson, i. 573.

veins, which traverse the independent coal formation [*]. It was discovered by Dr Withering; hence Werner has given it the name of *Witherite.* Usually massive, but sometimes crystallized. The crystals are very small and rare. Hence their primitive form has not been ascertained. They are six-sided prisms, terminated by six-sided pyramids, or double six-sided pyramids. Colour yellowish grey. Principal fracture intermediate between foliated and radiated; cross fracture uneven. Fragments wedge-shaped. Lustre of the principal fracture 2; of the cross 1, resinous. Massive varieties composed of wedge-shaped distinct concretions, passing into coarse granular. Transparency 2 to 3. Hardness 5 to 6. Brittle. Specific gravity 4·3 to 4·338. Frangibility 4. When heated it becomes opaque. Its powder phosphoresces when thrown on burning coals [†].

According to the analysis of Klaproth, the constituents of this mineral are as follows:

Constituents.

Carbonate of barytes ..	98·246
Carbonate of strontian ..	1·703
Alumina with iron	0·043
Carbonate of copper	0·008
	100·000 [‡]

Sp. 2. *Sulphate of Barytes* [§].

Ponderous spar—Baroselenite.

This mineral is found almost always in veins, and frequently accompanies metallic ores; sometimes, however, it occurs in beds and imbedded. It is sometimes

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[*] Watt, junior, Jameson's *Min.* i. 576.

[†] Hauy.

[‡] *Beitrage*, ii. 86.

[§] Kirwan, i. 138.—Brochant, i. 617.—Hauy, ii. 295.—Jameson, i. 597.

Salts of Barytes.

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 amount to 14. 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 the crystals are needleform.

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 4·5. 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. Werner divides this species into eight subspecies; namely, *earthy*, *compact*, *granular*, *curved lamellar*, *straight lameller*, *columnar*, *prismatic*, and *bolognese*. For a minute description of these subspecies I refer the reader to Professor Jameson's Mineralogy.

The granular subspecies is one of the rarest. It has considerable resemblance to *granular* lime-stone; but is easily distinguished by its greater specific gravity, which amounts to 4·380. A specimen from Peggau, analysed by Klaproth, was composed of

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* Hauy, *Essai d'une Theorie*, p. 119. † *Crystal.* i. 588.

‡ Ibid. and *Ann. de Chim.* xii. 3. and *Miner.* ii. 298.

Sulphate of barytes......	90
Silica	10
	100 *

Genus III. Strontian Salts.

This genus contains only two species; namely, the *carbonate* and *sulphate*.

Sp. 1. *Carbonate of Strontian—Strontianite.*

This mineral was first discovered in the lead mine of Strontian in Argyleshire; and since that time it is said to have been discovered, though not in great abundance, in other countries. It is found amorphous and also crystallized in needles, which, according to Hauy, are regular six-sided prisms.

Colour between asparagus and apple green, sometimes greenish white. Principal fracture is radiated, the rays diverging; cross fracture uneven. Lustre of principal fracture 3, 2; of cross fracture 2, pearly. Transparency 2. Hardness 5. Specific gravity from 3·4 to 3·675. Does not decrepitate when heated. Before the blow-pipe 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.

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* Klaproth's *Essays*, i. 376, Eng. Transl.

Strontian Salts.

Sp. 2. Sulphate 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. It occurs often massive, but frequently crystallized. The primitive form of its crystals is a four-sided prism, whose bases are rhombs, with angles of 104° 48′ and 75° 12′. The varieties of its crystals, as described by Hauy, amount to seven*. They may be referred to four or six sided prisms, terminated by two, four, or eight sided summits. Scratches calcareous spar, is scratched by fluor spar. Specific gravity from 3·5827 to 3·9581. Causes a double refraction. It may be divided into three subspecies †.

Subspecies 1. *Compact Sulphate.* This mineral is found in Montmartre near Paris. Colour yellowish grey. Found massive in round pieces. Lustre 0. Fracture fine splintery. Opaque. Frangibility 4. Sectile. Specific gravity 3·5 to 3·596. Contains, according to Vauquelin, 91·42 sulphate of strontian

91·42	sulphate of strontian
8·33	carbonate of lime
0·25	oxide of iron
100·00 ‡	

Subspecies 2. *Fibrous Sulphate.* Colour between indigo blue and bluish grey; sometimes passes into milk white. Massive and crystallized. Lustre of longi-

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* *Miner.* ii. 315.

† Brochant, i. 642.

‡ *Jour. de Min.* No. liii. 355.

Book III. Chap. II.

tudinal fracture 3; of cross fracture 2, between pearly and resinous. Longitudinal fracture foliated; cross fracture fibrous. Fragments splintery. Has a tendency to prismatic distinct concretions. Frangibility 4. Transparency 2. Specific gravity 3·83.

Subspecies 3. *Foliated Sulphate.* Colour milk white, often falling into blue. Found massive and in crystals. Crystals grouped. Lustre of the crystals 3 to 4. Their texture straight foliated. Transparency 2 to 4. Found in Sicily and in Britain. This subspecies has lately been divided by Werner into two varieties, the tabular and the prismatic; for a description of which the reader is referred to Professor Jameson[*].

GENUS IV. MAGNESIAN SALTS.

THIS genus contains three species; the sulphate, carbonate, and borate.

Sp. 1. *Sulphate of Magnesia.*

This salt is frequently found effloresced on the surface of rocks, walls, &c. in different parts of the world. Klaproth has shown that the substance from Idria, distinguished by the Germans by the name of *Haarsalz*, is sulphate of magnesia nearly pure[†].

Sp. 2. *Carbonate of Magnesia.*

If the analysis by Mitchell and Lampadius of the native magnesia, described in page 320th of this volume, be correct, it is in reality a carbonate of magnesia, and

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[*] *Mineralogy*, ii. 607.

[†] *Beitrage*, iii. 104.

should be placed here; but as the specimen examined by Giobert gave a different result, and as it is connected with the soap-stone family, the other seemed at present the preferable situation.

Sp. 3. *Borate of Magnesia* [*]—*Boracite.*

This mineral has been found at Kalkberg, near Luneburg, seated in a bed of gypsum. 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; usually much less.

Internal lustre 2, 3, between adamantine and vitreous. Fracture between imperfect small conchoidal and fine-grained uneven. External lustre 3; internal, greasy 2. Transparency from 2 to 3. Hardness 8. Specific gravity 2·566. Colour yellowish, smoke, and greyish white; sometimes passing into greenish white and asparagus green. 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 [||].

Besides borate of magnesia, Westrumb found in it lime in a considerable quantity; but a more recent ana-

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[*] Kirwan, i. 172.—Brochant, i. 589.—Hauy, ii. 337.

[†] Hauy, *Jour. de Min.* No. xxviii. 325.

[‡] Hauy and Westrumb.

[§] Hauy, Ibid. and *Ann. de Chim.* ix. 59.

[||] Le Lievre, *Jour. de Min.* Ibid.

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lysis of Vauquelin and Schmidt has shown, that the lime was merely mixed in the state of a carbonate: probably it disappears in the pure specimens.

Genus V. Aluminous Salts.

This genus comprehends three species; namely, *alum*, *mellite*, and *chriolite*.

Sp. 1. *Alum.*

This salt is found in crystals, soft masses, flakes, &c. encrusting coal, alum-slate, &c.

Sp. 2. *Mellite*[*].

Honeystone—Mellate of Alumina.

This mineral was first observed about ten years ago in Thuringia, between layers of bituminous wood and earth coal. It is of a honey-yellow colour (hence its name), and is usually crystallized in small octahedrons, whose angles are often truncated. Surface smooth. Lustre 4. Transparency 2. Refracts doubly. Fracture perfect 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.

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[*] Emmerling's *Lehrbuch*, ii. 89.—Wiedeman's *Handbuch*, p. 639.—Abich, Crell's *Annals*, 1797, ii. 3.—Vauquelin, *Ann. de Chim.* xxxvi. 23.—Klaproth, *Beitrage*, iii. 115.—Kirwan's *Min.* ii. 68.—Karsten, *Mus. Leck.* ii. 335.—Brochant, ii. 73.—Hauy, iii. 335.—Jameson, ii. 96.

Sp. 3. *Chriolite* *.

Fluate of Soda-and-Alumina.

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 greyish white. Fracture imperfect foliated. Fragments cubic or tabular. Transparency 2. Hardness inferior to that of fluate of lime. Brittle. 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:

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.—Jameson, ii. 558.

† Hence its name from κρυος and λιθος, as if it melted as easily as ice.

CLASS II.

SALTS.

UNDER this Class I comprehend all the combinations of alkalies with acids which exist in the mineral kingdom. They constitute the following genera and species.

GENUS I. POTASH.
- *Sp.* 1. Nitrate of potash.

GENUS II. SODA.
- *Sp.* 1. Carbonate of soda,
- 2. Sulphate of soda,
- 3. Glauberite,
- 4. Muriate of soda,
- 5. Borax.

GENUS III. AMMONIA.
- *Sp.* 1. Muriate of ammonia.

GENUS I. SALTS OF POTASH.

Sp. 1. *Nitrate of Potash.*

THIS salt is found native, mixed with nitrate of lime, muriate of potash, and other impurities, encrusting the surface of the earth, in different parts of India, the Cape of Good Hope, Peru, Spain, Molfetta, &c. It is most commonly in fine capillary crystals. Sometimes, though rarely, massive or in six-sided prisms. A specimen

Salts of Soda.

of native nitre from Molfetta, analysed by Klaproth, contained

44·55 nitrate of potash
25·45 sulphate of lime
30·40 carbonate of lime
0·20 muriate of potash

100·00

GENUS II. SALTS OF SODA.

Sp. 1. *Carbonate of Soda.*

THIS salt is found in Egypt on the surface of the earth, and on the margin of certain lakes which become dry during the summer. It has often the appearance of a rough dusty powder, of a grey colour and alkaline taste. It occurs in China, where it is called *kien;* near Tripoli, where it is denominated *trona;* and likewise in Hungary, Syria, Persia, and India*.

There are two kinds of it; the subcarbonate, which is in greyish or yellowish white flakes, and the carbonate, which forms solid radiated masses composed of acicular crystals, and has hitherto been found only in Africa.

A specimen of the first kind from Egypt was found by Klaproth to consist of

32·6 dry subcarbonate of soda
20·8 dry sulphate of soda
15·0 dry muriate of soda
31·6 water

100·0†

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* Kirwan's *Min.* ii. 6.

† *Beitrage,* iii. 80.

A specimen of the second, or fibrous carbonate, from the interior of Africa, yielded the same chemist

37·0	soda
38·0	carbonic acid
22·5	water
2·5	sulphate of soda
100·0 *	

Sp. 2. *Sulphate of Soda.*

This salt is found in Austria, Hungary, Stiria, Switzerland, and Siberia, always in the neighbourhood of a mineral spring. It occurs usually in the state of powder, sometimes massive, and even crystallized in needles and six-sided prisms. Colour greyish or yellowish white.

Sp. 3. *Glauberite* †.

This mineral has been lately discovered in Spain, at Villarubia near Ocanna in New Castile. Its crystals are sometimes solitary, sometimes in clusters, and disseminated in masses of salgem. Always crystallized. Crystals in the form of an oblique prism with a rhombic base. The angles of the parallelogram constituting the base are 76° and 104°. The angles of incidence between the parallelogram of the base and the adjacent sides are 142° ; that between the base and the edge contiguous to the acute angle of the base is 154°. The faces of the base smooth, those of the sides longitudinally striated.

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[*] *Beitrage*, iii. p. 87.

[†] Brogniart, Nicholson's *Jour.* xxiv. 65.

Salts of Soda.

The crystals are of a light topaz yellow, and retain their solidity and transparency in the air if they have not been wetted. Harder than sulphate of lime, but softer than calcareous spar. When heated it splits; decrepitates and melts into a white enamel. Immersed in water it soon becomes white and opaque. When taken out of the water and dried, it does not resume its transparency; but the white coating falls to powder, and when rubbed off discovers the nucleus unchanged. Specific gravity 2·73. Composed of

51	anhydrous sulphate of soda
49	anhydrous sulphate of lime
100	

It contains no water of crystallization.

Sp. 4. *Muriate of Soda.*

Common salt is found in immense masses under the earth's surface in many countries, particularly in Poland, Hungary, England, &c. Near Cordova in Spain there is said to be a mountain of common salt 500 feet high, and nearly three miles in circumference. It occurs in beds, which are usually very short and thick, and lie over the oldest floetz gypsum formation *. Werner divides it into two subspecies; namely, *rock salt* and *lake salt*. The latter is salt deposited at the bottom of lakes. *Rock salt* he subdivides into two varieties, from the fracture and appearance; namely, *foliated* and *fibrous*. For a particular description of these

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* Jameson's *Min.* ii. 13.

the reader is referred to Professor Jameson's Mineralogy [*].

Sp. 5. *Borax.*

This mineral is found in different parts of Thibet, &c. It is usually mixed with foreign bodies; that of Persia is in large crystals, enclosed in a fatty matter. The primitive form of its crystals is a rectangular prism, but it occurs usually in six-sided prisms, whose edges are variously truncated. Its colour is greyish, yellowish, or greenish white. Fracture foliated or conchoidal. Transparency 2·3. Refracts doubly [†]. Tastes sweet and somewhat acrid.

Its constituents, according to the analysis of Klaproth, are

37·0	boracic acid
14·5	soda
47·0	water
1·5	loss
100 [‡]	

Genus III. Salts of Ammonia.

Sp. 1. *Muriate of Ammonia.*

This salt occurs near volcanoes, of which it is a product. It is found also in Persia. It is found usually in the state of powder in the middle of lava; sometimes in mass, and even in very irregular crystals. Colour white, often with a shade of yellow or green. Very soft.

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[*] Vol. ii. p. 10.

[†] Hauy, ii. 366.

[‡] *Beitrage*, iv. 350.

Salts of Ammonia.

A specimen of this salt from Tartary yielded Klaproth

97·5 muriate of ammonia
2·5 sulphate of ammonia

100·0 [*]

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[*] *Beitrage*, iii. 94.

CLASS III.

COMBUSTIBLES.

THIS class comprehends all the combustible substances which constitute a part of the mineral kingdom, except the diamond and the mellite, which have been already described, and the metals which belong to the fourth class of minerals. They have been divided into four genera; namely,

1. Sulphur 3. Bitumen
2. Resin 4. Graphite.

GENUS I. SULPHUR.

THIS genus comprehends only one species, namely, *native sulphur;* though perhaps *orpiment*, usually placed among the ores of arsenic, might, without impropriety, be referred to it.

Sp. 1. *Native Sulphur* [*].

This mineral occurs commonly in masses of gypsum, lime-stone, and marl. It is sometimes found in veins traversing primitive rocks; and Humboldt lately observed

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[*] Kirwan, ii. 69.—Brochant, ii. 37.—Hauy, iii. 277.—Jameson, ii. 38.

Resin.

it in South America in mica slate, constituting a bed along with quartz. Colour sulphur yellow, passing into honey, lemon, and wax yellow, with a mixture of grey or brown. Massive, disseminated, and crystallized. The primitive form of its crystals is an octahedron, composed of two four-sided pyramids, joined base to base. The sides of these pyramids are scalene triangles, and so inclined that the plane where the bases of the pyramids join is a rhomb, whose long diagonal is to its short as 5 to 4 *. Sometimes the apices of the pyramids, to use the language of Romé de Lisle, are truncated; sometimes they are separated from each other by a prism; sometimes they are truncated near their bases, and a low four-sided pyramid rises from the truncature: this pyramid is also sometimes truncated near its apex. Finally, one of the edges of the pyramids is sometimes truncated. For figures of these varieties, and for the laws of their formation, the reader is referred to Mr Lefroy †.

Surface of the crystals smooth. Lustre 4; internal lustre 3, 2, adamantine. Fracture small-grained uneven, passing into splintery. Fragments blunt-edged. Transparency 2; of the crystals 3, 4; refracts doubly. Very soft. Frangibility 6.

The sulphur in the neighbourhood of volcanoes differs somewhat in its properties from common native sulphur.

GENUS II. RESIN.

This genus comprehends two species; namely, *amber* and *retinasphaltum*.

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* Romè de Lisle, i. 292.—Hauy and Lefroy, *Jour. de Min.* No. xxix. 337.

† *Jour. de Min.* No. xxix. 337.

Sp 1. *Amber.*

This substance, called *electrum* by the ancients, is found in different countries; but most abundantly in Prussia, either on the sea-shore, or under ground at the depth of about 100 feet, reposing on *wood coal**. It is in lumps of different sizes. Werner divides it into two subspecies: namely, *white* and *yellow amber*.

Subspecies 1. *White Amber.* Colour straw yellow; sometimes inclining to yellow white. Massive. Lustre 2, 3, resinous. Fracture conchoidal. Fragments sharp-edged. Transparency 2. In other respects agrees with the succeeding.

Subspecies 2. *Yellow Amber.* Colour wax yellow, passing into honey yellow, yellowish brown, and hyacinth red. In blunt-edged pieces with a rough surface. External lustre 0; internal 4, between resinous and vitreous. Fracture perfect large conchoidal. Fragments very sharp-edged. Transparency 4. Soft. Rather brittle. Frangibility 4. Specific gravity from 1·078 to 1·085.

Sp. 2. *Retinasphaltum.*

This mineral, found at Bovey, and lately described and analysed by Mr Hatchett, belongs to the resin genus, and connects this genus with that of the bitumens; retinasphaltum being a compound of resin and bitumen. For a description of it, see Vol. II. p. 509.

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* Kirwan, *Mineralogy*, ii. 66.

Bitumen.

GENUS III. BITUMEN.

THIS genus contains four species; namely, *petroleum*, *mineral pitch*, *brown coal*, and *black coal*.

Sp. 1. *Petroleum*, or *Mineral Oil*[*].

This substance usually flows from rocks of the coal formation, and generally from the immediate vicinity of coal. Colour brownish black. Liquid, but viscid. Transparency usually 2. Lustre 3, resinous. Feels greasy. Wets. Smell bituminous.

Sp. 2. *Mineral Pitch*.

The substances arranged under this species occur chiefly in veins. Werner divides it into three subspecies, *earthy*, *slaggy*, and *elastic mineral pitch*.

Subspecies 1. *Earthy Mineral Pitch*. This is the substance commonly known by the names of *mineral pitch* and *maltha*. Colour blackish brown. Massive. Lustre 0, 1; of streak 3, resinous. Fracture earthy or small grained uneven; sometimes nearly splintery. Fragments blunt-edged. Very soft. Sectile. Frangibility 3. Feels greasy. Light; almost swims on water. Smell bituminous.

Subspecies 2. *Slaggy Mineral Pitch*. Colour velvet black; sometimes approaching brownish black. Massive. Internal lustre 4, 3, 2, resinous. Fracture imperfect, or perfect conchoidal. Fragments pretty sharp-edged. Very soft. Opaque. Sectile. Retains its

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[*] Kirwan, ii. 42.—Hatchett. *Linnæan Trans.* iv. 131.—Brochant, ii. 59.—Hauy, iii. 312.—Jameson, ii. 44.

lustre in the streak. Frangibility 3. Feels greasy. Specific gravity from 1·07 to 1·165. Smell bituminous.

Subspecies 3. *Elastic Mineral Pitch*, or *Mineral Caoutchouc*. Found in Derbyshire. Colour blackish brown ; sometimes inclining to brownish black, sometimes reddish brown. Internal lustre 3, 2, resinous ; of streak 3. Fracture curved slaty ; cross fracture conchoidal. Fragments slaty. Transparency 1. Very soft. Sectile. Flexible and elastic. Specific gravity from 0·9053 to 1·233. For a minute description of the varieties of this substance, the reader is referred to Mr Hatchett's paper in the Linnæan Transactions *.

Sp. 3. *Brown Coal.*

This important species has been divided by Werner into five subspecies ; namely, *bituminous wood, earth-coal, alum-earth, common brown coal*, and *moor-coal*.

Subspecies 1. *Bituminous wood* †. This mineral, which in its shape resembles the stems and branches of trees a little flattened, occurs along with common brown coal, usually in the floetz trap and alluvial formations. It is found at Bovey in Devonshire, and in Iceland is known by the name of *surturbrand*. Colour light ord ark brown, approaching wood brown or brownish black. Lustre of principal fracture 1, 2 ; of cross fracture 3 ; of the streak 3. Fracture in the great slaty,

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* Under the denomination of *asphaltum*, in Vol. II. p. 505, of this Work, I include the two first subspecies of mineral pitch.

† Kirwan, ii. 60.—Brochant, ii. 44.—Jameson, ii. 54.—Von Troil's *Letters on Iceland*, p. 42.—Hatchett, *Phil. Trans.* 1804.—Parkinson's *Remains of a Former World*, p. 104.

in the small fibrous; cross fracture sometimes imperfect conchoidal. Fragments commonly splintery. Opaque. Soft. Sectile. Flexible and somewhat elastic. Light.

Subspecies 2. *Earth Coal**. Found along with bituminous wood in the county of Mansfield, and on the Saal often in thick strata. It is kneaded with water in troughs, formed in moulds into the shape of bricks, and dried; in this state it is used as fuel. Colour blackish brown; sometimes passes into yellowish grey. Nearly loose. Particles dusty; soil a little. Internal lustre scarce 1; streak nearly 3. Falls to powder.

Subspecies 3. *Alum-Earth* †. Occurs in beds in alluvial land, and in the floetz trap formation. Colour blackish brown. Massive. Lustre 0; sometimes 1, from mica; of streak 3. Fracture earthy with a tendency to slaty. Fragments tabular. Feels meagre and sometimes greasy. Sectile. Between very soft and friable.

Subspecies 4. *Common Brown Coal* ‡. This mineral is found abundantly at Bovey. Colour light brownish black. Massive. Internal lustre 3, 2, resinous. Streak lighter. Fracture imperfect large conchoidal. Fragments sharp-edged. Soft. Sectile. Not very brittle. Frangibility 4. Light.

Subspecies 5. *Moor Coal* §. Found in Bohemia and other parts of Germany. Colour dark blackish brown.

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* Jameson, ii. 57.—Klaproth, iii. 319.

† Brochant, i. 383.—Jameson, ii. 61.—Klaproth, Gehlen's *Jour.* vi. 44.

‡ Mills, *Phil. Trans.* li. 534.—Brochant, ii. 47.—Scammell, Parkinson's *Remains of a Former World*, p. 126.—Jameson, ii. 62.—Hatchett, *Phil. Trans.* 1804.

§ Jameson, ii. 65.

Massive. Internal lustre 2, resinous; of streak 3. Principal fracture imperfect slaty; cross fracture even, approaching flat conchoidal. Fragments trapezoidal, approaching cubical. Soft. Sectile. Frangibility 6. Light. When exposed to the air it bursts and falls to pieces.

Sp. 4. *Black Coal**.

Under this species are included almost all the varieties of coal that are used in this country for fuel. It is divided into six subspecies; namely, *pitch*, *columnar*, *slate*, *cannel*, *foliated*, and *coarse coal*.

Subspecies 1. *Pitch Coal—Jet.* Occurs in all the three coal formations, but most commonly in that which belongs to the floetz trap. Colour velvet black; sometimes brownish black. Massive, in plates; sometimes in the shape of branches of trees, but without a regular woody texture. Internal lustre 3, 4, resinous. Fracture perfect large conchoidal. Fragments sharp-edged. Soft. Rather brittle. Frangibility 3. Specific gravity 1·308.

Subspecies 2. *Columnar Coal.* Hitherto found only in the Meissner in Hessia along with other subspecies. Colour between velvet and greyish black; sometimes inclining to iron blue. Massive. Internal lustre 3, 4, resinous, or inclining to semimetallic. Fracture imperfect conchoidal. Occurs in thick columnar distinct concretions with glimmering surfaces. Soft. Rather brittle. Frangibility nearly 6. Light. Burns without flame, leaving a greyish white ash.

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* Jameson, ii. 66.

Subspecies 3. *Slate-Coal.* This is the common coal of England and Scotland, occurring most commonly in the independent coal formation. Colour between velvet and dark greyish black. Massive. Lustre 3, 2, resinous. Principal fracture nearly perfect slaty; cross fracture small-grained uneven, passing into even and imperfect conchoidal. Fragments sometimes trapezoidal. Soft. Approaching to sectile. Frangibility 5. Specific gravity from 1·250 to 1·370 *.

Subspecies 4. *Cannel Coal.* Accompanies the preceding subspecies. Found at Wigan in Lancashire, and in various parts of Scotland. Colour dark greyish black. Massive. Internal lustre 2, resinous. Fracture sometimes flat large conchoidal, sometimes even. Fragments sometimes cubical. Frangibility 5. Specific gravity from 1·232 to 1·275. Often cut into various vessels and ornaments.

Subspecies 5. *Foliated Coal.* Found in Saxony and Silesia in the independent coal formation. Colour between velvet and greyish black. Massive. Lustre of principal fracture 4; of cross fracture 2, resinous. Longitudinal fracture straight foliated, with a single cleavage; cross fracture slaty. Fragments approaching to cubical. Soft. Approaches sectile. Frangibility 6. Light.

Subspecies 6. *Coarse Coal.* Occurs in the neighbourhood of Dresden. Colour dark greyish black. Massive. Lustre 2. Cross fracture coarse-grained uneven; longitudinal generally slaty. Fragments rather blunt-edged. Semihard; the hardest subspecies of

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* Kirwan.

coal. Rather brittle. Frangibility 4. Heavier than the preceding subspecies.

The following Table exhibits a view of the constituents of such of the preceding subspecies of brown and black coal as have been hitherto analysed:

Constituents.

Bituminous Wood *.	
Vegetable earth	54
Sulphur	0·8
Sulphate of iron	10·7
Oxide of iron	12·7
Sulphate of lime	·7
Silica	·2
Loss	20·9
	100·0

Earth Coal †.	
Volatile matter	62·25
Charcoal	20·25
Lime	2·0
Sulphate of lime	2·5
Oxide of iron	1·0
Alumina	0·5
Sand	11·5
	100·0

Alum Earth ‡.	
Charcoal	19·65
Sulphur	2·85
Silica	40·00
Alumina	16·00
Oxide of iron	6·40
Sulphate of iron	1·80
Sulphate of lime	1·50
Magnesia	0·50
Sulphate of potash	1·50
Muriate of potash	0·50
Water	10·75
	101·45

Bovey Coal §.	
Charcoal	45
Volatile matter	55
	100

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* Vauquelin, Jameson, ii. 55.

† Klaproth, iii. 319.

‡ Klaproth, Gehlen's *Jour.* vi. 44.

§ Hatchett, *Phil. Trans.* 1804.

Graphite.

	Slate Coal.		
	Of Walden.	Of Salrze.	Of Bielschowitz.
	[*]	[*]	[*]
Charcoal	57·99	63·31	58·17
Bitumen	36·87	32·93	37·89
Earth	5·82	3·90	3·94
Loss	1·32		
	102·00	100·14	100

GENUS IV. GRAPHITE.

THIS genus contains three species; namely, *glance coal, graphite*, and *mineral charcoal.*

Sp. 1. *Glance Coal*[†].

Glance coal, so called by the Germans on account of its great lustre, is divided by Werner into two subspecies, the first of which is much more uncommon than the second.

Subspecies 1. *Conchoidal Glance Coal.* Hitherto has been found only in the newest floetz trap formations. Colour iron black, rather inclining to brown. Surface tarnished like tempered steel. Massive and vesicular. Internal lustre 3, 4, metallic. Fracture large and small conchoidal. Fragments sharp-edged. Soft. Rather brittle. Frangibility 4. Light. Burns without flame or smell.

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[*] Richter, Jameson, ii. 73. A table of the constituents of several varieties of slate coal, and of cannel coal, according to Kirwan's and Mushet's experiments, has been given in Vol. ii. p. 511 and 512.

[†] Jameson, ii. 81.

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Subspecies 2. *Slaty Glance Coal—Anthracite—Kilkenny Coal.* Supposed peculiar to primitive and transition rocks till Professor Jameson discovered it in the independent coal formation in the island of Arran. Colour dark iron black, seldom inclining to brown. Massive. Lustre 3, 2, between metallic and semimetallic. Principal fracture more or less perfect slaty; cross fracture small flat conchoidal. Fragments pretty sharp-edged; sometimes trapezoidal. Soft. Frangibility 6. Between sectile and brittle. Specific gravity from 1·415 to 1·800.

This species consists of charcoal destitute of bitumen, either with or without an admixture of earthy matter.

Sp. 2. *Graphite**—*Plumbago.*

This species, like the last, is divided into two subspecies; namely, *scaly* and *compact graphite.*

Subspecies 1. *Scaly Graphite.* Colour dark steel grey, approaching to light iron black. Massive. Lustre 2, 1, metallic; of the streak 3, 4, metallic. Fracture scaly foliated; sometimes passing into large conchoidal; sometimes slaty and uneven. Fragments trapezoidal. In granular distinct concretions. Very soft. Sectile. Frangibility 2. Writes and soils. Feels very greasy. Specific gravity from 1·987 to 2·267 †.

Subspecies 2. *Compact Graphite.* Colour rather blacker than the preceding. Internal lustre 1, 2, metallic. Fracture fine-grained uneven, passing into even; also large flat conchoidal. In other characters agrees with the preceding subspecies.

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* Jameson, ii. 26.

† Kirwan.

It is a carbonate of iron often mixed with earthy matter.

Sp. 3. *Mineral Charcoal**.

Occurs along with the varieties of coal. Colour greyish black. In angular pieces inclining to a cubic form. Lustre 1, 2, silky. Fracture fibrous; sometimes shows the woody texture. Fragments blunt-edged; sometimes splintery. Soils strongly. Soft; passing into friable. Light.

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* Jameson, ii. 90.

CLASS IV.

ORES.

This class comprehends all the mineral bodies, composed either entirely of metals, or of which metals constitute the most considerable and important part. It is from the minerals belonging to this class that all metals are extracted; for this reason they have obtained the name of *ores*.

As the metals at present known amount to 28, I should divide this class into 28 orders, allotting a distinct order for the ores of every particular metal; but there are 4 metals which have been hitherto found only in other ores. Thus the orders are reduced to 24.

Metals exist in ores in one or other of the four following states: 1. In a metallic state, and either solitary or combined with each other; 2. Combined with sulphur; 3. In the state of oxides; 4. Combined with acids. Each order therefore may be divided into the four following genera.

1. Alloys.	3. Oxides.
2. Sulphurets.	4. Salts.

It must be observed, however, that every metal has not hitherto been found in all these four states, and that some of them are hardly susceptible of them all.

Some of the orders therefore want one or more genera, as may be seen from the following Table.

Table of the genera.

ORDER I. *Gold*
  1. Alloys
ORDER II. *Platinum*
  1. Alloys
ORDER III. *Iridium*
  1. Alloys
ORDER IV. *Silver*
  1. Alloys
  2. Sulphurets
  3. Oxides
  4. Salts
ORDER V. *Mercury*
  1. Alloys
  2. Sulphurets
  3. Salts
ORDER VI. *Copper*
  1. Alloys
  2. Sulphurets
  3. Oxides
  4. Salts
ORDER VII. *Iron*
  1. Alloys
  2. Sulphurets
  3. Oxides
  4. Salts
ORDER VIII. *Nickel*
  1. Alloys
  2. Oxides
ORDER IX. *Tin*
  1. Sulphurets
  2. Oxides
ORDER X. *Lead*
  1. Sulphurets
  2. Oxides
  3. Salts
ORDER XI. *Zinc*
  1. Sulphurets
  2. Oxides
  3. Salts
ORDER XII. *Bismuth*
  1. Alloys
  2. Sulphurets
  3. Oxides
ORDER XIII. *Antimony*
  1. Alloys
  2. Sulphurets
  3. Oxides
  4. Salts
ORDER XIV. *Tellurium*
  1. Alloys
ORDER XV. *Arsenic*
  1. Alloys
  2. Sulphurets
  3. Oxides
  4. Salts
ORDER XVI. *Cobalt*
  1. Alloys
  2. Oxides
  3. Salts
ORDER XVII. *Manganese*
  1. Oxides
  2. Salts

ORDER XVIII. *Chromium*
1. Alloys
2. Oxides
3. Salts
ORDER XIX. *Uranium*
1. Oxides
ORDER XX. *Molybdenum*
1. Sulphurets
ORDER XXI. *Tungsten*
1. Salts
ORDER XXII. *Titanium*
1. Oxides
ORDER XXIII. *Columbiu*
1. Oxides
ORDER XXIV. *Cerium*
1. Oxides

ORDER I. ORES OF GOLD.

Situation.

No metal, perhaps, if we except iron, is more widely scattered through the mineral kingdom than gold *. Hitherto it has been found only in a metallic state; most commonly in grains, ramifications, leaves, or small crystals. Occurs in gneiss, mica, slate, clay-slate, also in veins. It is generally mixed with quartz, though there are instances of its having occurred in calcareous rocks. It is not uncommon also to find it disseminated through the ores of other metals; especially iron, mercury, copper, and zinc. The greatest quantity of gold is found in the warmer regions of the earth. It abounds in the sands of many African rivers, and is very common in South America and India. Europe, however, is not destitute of this metal. Spain was famous in ancient times for its gold mines, and several of the rivers in France contain it in their sands †. But the principal gold mines in Europe are those of Hungary, and next to them those of Saltzburg. Gold also has

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* Bergman.

† Reaumur, *Mem. Par.* 1718, p. 68.

been discovered in Sweden and Norway, and more lately in the county of Wicklow in Ireland *.

Sp. 1. *Native Gold* †.

Found disseminated in grains, plates, and small crystals; commonly in cubes, octahedrons, and rhomboidal dodecahedrons. Fracture hackly. Soft. Ductile. Flexible, but not elastic. Very heavy. Native gold is never completely pure; it is alloyed with some silver or copper, and sometimes with iron. In the native gold found in Ireland, indeed, the quantity of alloy appears to have been exceedingly small. Werner divides this species into three subspecies, according to the metal with which the gold is alloyed.

Subspecies 1. *Pure Gold.* Colour gold yellow. It contains only a very minute proportion of silver or copper.

Subspecies 2. *Brass Yellow Native gold.* Colour brass yellow. Alloyed with a greater proportion of silver or copper.

Subspecies 3. *Greyish yellow Native gold.* Colour between steel grey and brass yellow. Supposed to contain a portion of platinum.

Sp. 2. *Electrum* ‡.

The term *electrum*, applied by the ancients to a mixture of gold and silver, has been given by Klaproth to

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* Lloyd, *Phil. Trans.* 1796, p. 36.—Mills, Ibid. p. 38.—Nicholson's *Journal*, ii. 224.

† Brochant, ii. 89.—Hauy, iii. 374.—Jameson, ii. 104.

‡ Klaproth, *Beitrage*, iv. 1.

an ore from Schlangenberg in Siberia, which he found by analysis to be a compound of these two metals.

Its colour is pale golden yellow. It occurs in solitary plates, needles, or imperfect cubes, scattered sometimes in a grey coloured sulphate of barytes, sometimes in hornstone. It is composed of

64 gold
36 silver

100

ORDER II. ORES OF PLATINUM *.

HITHERTO no mine of platinum has been discovered. It is found in small scales or grains in the sands of the river Pinto, at Choco, Popayen, and Quito in Peru, and near Carthagena in South America. Repository unknown. It occurs also in Brazil in the silver mines of that country, and in the same state of small grains as in Peru. It is also accompanied by the four new metals which are found in the Peruvian platinum †.

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* See Brownrigg, *Phil. Trans.* xlvi. 584.—Lewis, Ibid. xlviii. 638. and l. 148.—Margraf, *Mem. Berlin.* 1757, p. 314.—Macquer, *Mem. Par.* 1758, p. 119.—Buffon, *Jour. de Phys.* iii. 324.—Morveau, Ibid. vi. 193.—Bergman, *Opusc.* ii. 166.—Tillet, *Mem. Par.* 1779, p. 373. and 385. and 545.—Crell, Crell's *Annals*, 1784, 1 Band. 328.—Willis, *Manchester Memoirs*, ii. 467.—Mussin Puschkin, *Ann. de Chim.* xxiv. 205.—Morveau, Ibid. xxv.—Proust, Ibid. xxxvi. 146.—Brochant, ii. 86.—Hauy, iii. 368.—Jameson, ii. 100.

† Wollaston, *Phil. Mag.* xxxiii. 250. Vauquelin has lately detected platinum in the silver mine of Guadalcanal in Estremadura, a province of Spain. In the ore of that mine it is in the metallic state, sometimes in very minute quantity, sometimes in the proportion of 10 *per cent.* In

GENUS I. ALLOYS OF PLATINUM.

Sp 1. *Native Platinum—Platina.*

Colour very light steel grey, which approaches silver white. Occurs in small grains, sometimes a little convex on one side. Lustre 3, 2, metallic. Fracture not determined. Soft. Malleable. Flexible. Specific gravity never exceeds 17·7 *. Soluble in nitro-muriatic acid.

ORDER III. ORE OF IRIDIUM.

Situation.

HITHERTO this ore has been found only mixed with that of platinum, in grains so nearly similar to those of that ore as scarcely to be distinguishable by the eye. It was first discovered by Dr Wollaston, who treated crude platina in considerable quantities with nitro-muriatic acid. The ore of iridium remained behind, not being in the least acted on by that menstruum.

The ore of iridium is harder than crude platina, is not malleable, appears to be composed of plates of a peculiar lustre. Specific gravity 19·5. Composed of osmium and iridium alloyed together †.

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this ore it is not mixed with the four newly discovered metals which accompany American platinum. This is the first well authenticated instance of the discovery of platinum in the Old Continent. *Ann. de Chim.* lx. 317.

[*] Wollaston.

[†] Wollaston, *Phil. Trans.* 1805.

ORDER IV. ORES OF SILVER.

Silver, like gold, is found most abundantly in the tropical regions. It occurs usually in the newest primitive formations, and most of the species have been observed only in veins. The following Table exhibits a view of the ores of this metal at present known.

Table of the Species.

I. ALLOYS
- Native silver
- Auriferous
- Antimonial
- Arsenical

II. SULPHURETS
- Common sulphuret
- Antimonial
- White silver ore

III. OXIDES
- Red silver ore

IV. SALTS
- Muriate
- Carbonate
- Sulphureted muriate

GENUS I. ALLOYS OF SILVER.

Sp. 1. *Native Silver* *.

NATIVE silver, so called because the silver is nearly in a state of purity, forms the principal part of some of the richest silver mines in the world. It is sometimes in small lumps; sometimes crystallized in cubes, hexahedrons, octahedrons, or dodecahedrons; sometimes in leaves, or threads, often so connected with each other as to resemble branches of trees, and therefore called *dendrites*. The silver in the famous mines of Potosi has

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* Kirwan, ii. 108.—*Calling. Act. Liter. Sveciæ*, 1738, p. 420.—Brochant, ii. 114.—Hauy, iii. 384.—Jameson, ii. 133.

Alloys.

this last form. When newly extracted, it is not unlike small branches of fir [*].

The colour of native silver is white; often tarnished. Lustre metallic. Fracture hackly. Hardness 6. Malleable. Specific gravity from 10 to 10·338.

The silver in this species is almost constantly alloyed with from ·03 to ·05 of some other metal, frequently gold or arsenic.

Sp. 2. *Auriferous Silver* [†].

This alloy is uncommon. It has been observed at Konigsberg in Norway, and at Schlangenberg in Siberia. Its colour is yellowish white. Its lustre metallic. Hardness 5. Malleable. Specific gravity above 10·6. This, I presume, is the ore described in the first order under the name of *electrum*.

Sp. 3. *Antimonial Silver Ore* [‡].

This alloy is found in the silver mines of Spain and Germany, and is sometimes in grains or lumps, and sometimes crystallized in four and six sided prisms, whose sides are longitudinally streaked [§].

Colour between silver and tin white. Its lustre metallic. Hardness 8. Specific gravity from 9·4406 [‖] to 10 [¶]. Fracture perfect foliated. In granular distinct concretions. Sectile. Frangibility 3. Before the

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[*] Bergman, *Phys. Geogr.*—*Jour. de Min.* No. xvi. p. 26.

[†] Brochant, ii. 216.—Jameson, ii. 141.

[‡] Kirwan, ii. 110.—Brochant, ii. 119.—Klaproth, iii. 173.—Hauy, iii. 391.—Jameson, ii. 142.

[§] Rome de Lisle, iii. 461.

[‖] Hauy, *Jour. de Min.* No. xxx. 473.

[¶] Kirwan, ii. 11.

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blow-pipe the antimony evaporates in a grey smoke, and leaves a brownish slag, which tinges borax green. If borax be used at first a silver bead may be obtained.

This alloy was supposed to contain arsenic, till Bergman examined it, and found only silver and antimony [*].

Sp. 2. *Arsenical Silver Ore* [†].

This ore is very rare, and has hitherto been found chiefly at Andreasberg in the Hartz. Colour tin white. Found disseminated in round masses, and crystallized in six-sided prisms and pyramids. Lustre metallic. Fracture foliated. Soft. Sectile. Frangibility 3. Very heavy. Before the blow-pipe arsenic flies off, and a button of silver remains.

The following Table exhibits the constituents of such of the preceding species as have been subjected to chemical analysis.

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[*] *Opusc.* ii. 415.

[†] Kirwan, ii. 111.—Brochant, ii. 122.—Hauy, iii. 396.—Jameson, ii. 145.

Sulphurets.

Constituents.

	Auriferous Silver.	Antimonial Silver Ore.				Arsenical Silver.
	*	†	†	†	‡	§
Silver	72	84	77	76	78	12·75
Gold	28					
Antimony		16	23	24	22	4
Arsenic						35
Iron						44·25
Loss						4
	100	100	100	100	100	100

GENUS II. SULPHURETS.

Sp. 1. *Common Sulphuret of Silver* ‖.

Vitreous Silver Ore—Silver Glance.

THIS ore occurs in the silver mines of Germany and Hungary. It is sometimes in masses, sometimes in threads, and sometimes crystallized. Its crystals are either cubes or octahedrones, or rhomboidal dodecahedrons, whose angles and edges are often variously truncated. For a description of the varieties produced by these truncatures, the reader is referred to Romé de Lisle ¶ and Hauy **.

Its colour is dark blackish lead grey, often tarnished. Internal lustre metallic. Fracture small-grained un-

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[*] Fordyce, *Phil. Trans.* 1776, p. 532.

[†] Klaproth, *Beitrage*, ii. 301. and iii. 175.

[‡] Vauquelin, Hauy, iii. 392.

[§] Klaproth, *Beitrage*, i. 187.

[‖] Kirwan, ii. 115.—Brochant, ii. 134.—Hauy, iii. 398.—Jameson, ii. 155.

[¶] *Crystall.* iii. 441.

[**] *Miner.* iii. 399.

even. Hardness 4 to 5. May be cut with a knife like lead. Flexible and malleable. Specific gravity 6·909 * to 7·215 †. In a gentle heat the sulphur evaporates. Melts when heated to redness.

Sp. 2. Antimonial Sulphuret ‡—*Brittle Silver Ore.*

This ore occurs chiefly in Saxony and Hungary, always in veins, and usually accompanies dark red silver ore. Colour between iron black and dark lead grey. Massive, and crystallized in six-sided prisms, lenses, and four-sided tables variously truncated. External lustre 4; internal 3, 2, metallic. Fracture coarse and fine grained uneven; of the crystals imperfect small conchoidal. Streak retains the colour and lustre. Soft. Brittle. Frangibility 5. Specific gravity 7·208 §. Before the blow-pipe the sulphur and antimony exhale, leaving a bead, which may be freed from iron by fusion with nitre and borax.

Sp. 3. White Silver Ore ||.

This ore occurs in considerable quantities in the mine of Himmelfurst in Saxony. Colour light lead grey. Massive. Internal lustre 2, 3, metallic. Fracture usually even. Soft. Slightly sectile. Frangibility 5. Specific gravity 5·322, according to Gmelin.

The following Table exhibits the analysis of the species belonging to this genus.

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* Brisson.

† Gellert.

‡ Kirwan, ii. 117.—Brochant, ii. 138.—Haüy, iii. 416.—Jameson, ii. 160.

§ Gellert.

|| Kirwan, ii. 119.—Brochant, ii. 150.—Jameson, ii. 174.

Sulphurets.

Constituents.

	Sulphuret.			Antimonial Sulphuret.	White Silver Ore.	
	*	*	†	‡	§	§
Silver	84·81	85	84	66·5	20·40	9·25
Sulphur	14·19	15	16	12·0	12·25	22
Antimony				10·0	7·88	21·5
Lead					48·06	41
Iron				5·0	2·25	1·75
Arsenic				0·5		
Silica				1	0·25	0·75
Alumina					7	1
Loss	1·00			5	1·91	2·75
	100	100	100	100	100	100

GENUS III. OXIDES.

Sp. 1. *Red Silver Ore* [‖].

THIS ore is very common in several German silver mines. It occurs in masses, disseminated, and crystallized. Werner subdivides it into two subspecies, distinguished by their colour and geognostic situation: the second being usually accompanied by native arsenic and white cobalt ore, orpiment, and sulphate of bary-

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[*] Klaproth, *Beitrage*, i. 172. [†] Sage, Hauy, iii. 398.

[‡] Klaproth, *Beitrage*, i. 166. Under the arsenic a little iron is included. [§] Ibid. p. 172 and 175.

[‖] Kirwan, ii. 123.—Scopoli *de Minera Argenti Rubra*.—Sage, *Jour. de Phys.* xxxiv. 331. and xli. 370.; and *Nouv. Jour. de Phys.* ii. 284.—Westrumb, *Jour. de Phys.* xliii. 291. Klaproth, *Beitrage*, i. 141.—Brochant, ii. 143.—Hauy, iii. 402.—Proust, *Jour. de Phys.* lix. 403.—Jameson, ii. 164.

tes; the first by galena, antimonial sulphuret of silver, quartz, calcareous spar, and pyrites.

Subspecies 1. *Dark Red Silver Ore.* Colour between cochineal red and lead grey. Massive, disseminated, and crystallized in equiangular six-sided prisms, often variously truncated. Primitive form an obtuse rhomboid, whose plane angles are 104° 28′ and 75° 32′, and the inclination of the faces 109° 28′ and 70° 32′*. External lustre 4; sometimes metallic, sometimes adamantine. Internal lustre 3, 2, metallic or semimetallic. Fracture usually coarse and small grained uneven. Crystallized varieties imperfect small conchoidal. Fragments indeterminate, blunt edged. Transparency of the massy varieties 0; of the crystals 3, 4, 2. Streak cochineal red. Soft. Sectile. Frangibility 4. Specific gravity from 5·563 to 5·608. Before the blowpipe decrepitates, melts with slight bubbling, emitting a dense smoke, which colours the charcoal yellow, and leaves a button of silver.

Subspecies 2. *Light Red Silver Ore.* Colour passes from carmine red to a medium between cochineal red and lead grey. Massive, disseminated, and crystallized in acute six-sided prisms, often variously truncated. Internal lustre from 4 to 2, adamantine. Fracture usually imperfect small conchoidal; sometimes passing into coarse and small grained uneven, sometimes to imperfect foliated. Fragments indeterminate, pretty sharp-edged. Transparency of the massive 1, of the crystals 4. Streak aurora red. Soft. Sectile. Frangibility 6. Specific gravity 5·443 to 5·592. Becomes

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* Hauy, iii. 403.

Oxides.

electric by friction, but only when insulated [*]. Soluble in nitric acid with effervescence [†]. Before the blow-pipe melts, blackens, burns with a blue flame, gives out a white smoke with a slight garlic smell, and leaves a silver bead [‡].

The composition of this ore was long ambiguous. The older chemists considered it as a combination of silver, arsenic, and sulphur; and Bergman, in several parts of his work, has given us these bodies as its constituents [§]. Klaproth analysed it in 1793, and found only silver, sulphur, antimony, and oxygen [||]. Vauquelin confirmed this discovery soon after, and showed from his experiments, that the metals in the ore were in the state of oxides [¶]. His opinion was founded upon the solution of the ore in nitric acid without effervescence, which has been lately denied by Proust. This last chemist has shown that there are two kinds of red silver ore, the one containing arsenic, the other antimony [**]. Though he has not described the specimens which he subjected to analysis, yet it is probable, from several circumstances, that the first of our subspecies is that which contains the arsenic, and the second subspecies the antimony. The following Table exhibits a view of the different analyses of this ore hitherto made:

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[*] Hauy, *Jour. de Min.* xxx. 476.

[†] Ibid. xxxi. 518.

[‡] Vauquelin, Ibid.

[§] *Sciagraphia*, Engl. Trans. p. 80. *Opusc.* ii. 298.

[||] *Beitrage*, i. 141.

[¶] *Jour. de Min.* No. xvii. 1.

[**] *Jour. de Phys.* lix. 403.

Constituents.

	*	*	†	†	‡	§	§
Silver	60	62	54·27	56·67	61		
Antimony	20·3	18·5	16·13	16·13	19		
Arsenic					1·9		
Sulphur	11·7	11	17·75	15·07	11·1		
Oxygen			11·85	12·13			
Sulphuric acid	8·0	8·5			7		
Sulph. of silver						58	74·35
——antimony						33	
——arsenic							25
Oxide of iron						3	·65
Sand						3	
Water and loss						3	
	100	100	100	100	100	100	100

The analyses of Proust differs essentially from all the others, in exhibiting the metallic constituents, not in the state of oxides, but of pure metals.

Genus IV. Salts.

Sp. 1. *Muriate of Silver* [||].

Corneous Silver Ore—Horn Ore.

This ore occurs at Johanngeorgenstadt in Saxony, in South America, &c. always in veins, and usually in the upper part. It is often amorphous, sometimes nearly in powder, and sometimes crystallized in cubes or parallelopipeds.

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[*] Klaproth, *Beitrage*, i. 155.

[†] Vauquelin, *Jour. de Min.* No. xvii. p. 4. and 7.

[‡] Lampadius, *Handbuch, zur Chemischen Analyse der Mineral Korper.*

[§] Proust, *Jour. de Phys.* lix. 407. and 409.

[||] Kirwan, ii. 113.—Laxmann, *Nov. Comm. Petropol.* xix. 482.—Monnet, *Mem. Scav. Etrang.* ix. 717.—Brochant, ii. 127.—Hauy, iii. 418.—Jameson, ii. 148.

Most frequent colour pearl grey of all degrees of intensity; when exposed to the light it acquires a brownish tarnish. Internal lustre 3, 2, resinous; external 3 to 4. Acquires a gloss when scraped with a knife. Transparency 2 to 1. Fracture between imperfect flat conchoidal and fine-grained uneven. Hardness 4 to 5. Flexible. Malleable. Frangibility 3. Specific gravity 4·745 * to 4·804 †. Before the blowpipe it instantly melts, and gradually evaporates, but may be reduced by adding an alkali.

Constituents.

That this ore contains muriatic acid has been long known. Mr Woulfe first showed that it contained also sulphuric acid ‡; and this discovery has been confirmed by Klaproth, according to whose analysis this ore is composed of............67·75 silver
6·75 oxygen
6·00 oxide of iron
14·75 muriatic acid
·25 sulphuric acid
1·75 alumina

97·25 §

The alumina can only be considered as mixed with the ore. Sometimes its quantity amounts to ·67 of the whole ‖. Klaproth has published the analysis of a variety of this ore from Peru, which differs a good deal in its properies from the preceding.

Its colour is greyish and greenish white, passing into light olive green. Massive. Lustre 4, adamantine.

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* Brisson. † Gellert. ‡ *Phil. Trans.* 1776.
§ *Beitrage*, i. 134. ‖ Ibid. p. 137.

Fracture conchoidal. Fragments indeterminate. In large and small granular distinct concretions. Transparency 2. Very soft. Perfectly malleable. Very heavy. By Klaproth's analysis it is composed of

76·0	silver
7·6	oxygen
16·4	muriatic acid
100·0 *	

Sp. 2. *Carbonate of Silver* †.

This ore was discovered in 1788 by Mr Selb in the mine of Winceslas in Suabia. It is sometimes in masses, sometimes disseminated through other minerals.

Its colour is greyish black. Its streak bright. Its lustre metallic. Its fracture uneven. Hardness 4 to 5. Brittle. Specific gravity considerable. Effervesces with acids. Melts easily before the blow-pipe. Froths with borax.

Constituents.

According to Selb, it contains

72·5	silver
15·5	carbonate of antimony
12·0	carbonic acid
100·0	and a little copper

Sp. 3. *Silver Black* ‡—*Sooty Silver Ore.*

This mineral occurs in veins, and accompanies some of the other species of silver ores. Werner divides it into two subspecies.

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* *Beitrage*, iv. 10.

† Kirwan, ii. 112.—Brochant, ii. 155.

‡ Kirwan, ii. 117.—Brochant, ii. 132.—Jameson, ii. 610.

Subspecies 1. *Friable Silver Black.* Colour bluish black, approaching to lead grey. Friable. Disseminated, or as a coating. Internal lustre 0, 1. Composed of dull dusty particles. Lustre of streak 3, metallic. Scarcely soils. Heavy.

Subspecies 2. *Indurated Silver Black.* Colour the same as the preceding. Massive and disseminated. Lustre of principal fracture 1. Fracture between fine earthy and small and fine grained uneven. Fragments indeterminate blunt-edged. Streak shining and metallic. Very soft. Sectile, approaching to malleable. Frangibility 5. Heavy.

This species has not been analysed, but it is supposed to be a compound of oxide of silver, sulphur, and muriatic acid.

ORDER V. ORES OF MERCURY.

MERCURY is found in Europe, particularly in Spain, Germany, and Hungary: it is found also in China [*], the Philippines [†], and in Peru, and perhaps Chili [‡] in South America. The most productive mines of mercury are those of Idria [§]; of Almaden, near Cordova in Spain, which were wrought by the Romans [‖]; of the Palatinate [¶]; and of Guanca Velica in Peru [**].

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[*] See Entrecolle's *Lettres Edifiantes.*

[†] Carreri's *Voyages.*

[‡] See Molina's *Natural History of Chili.*

[§] Scopoli, *Jour. de Min.* No. xxxiv. p. 915.

[‖] See Bowle's *Natural History of Spain*, and *Jour. de Min.* No. xxxi. p. 355.

[¶] *Jour. de Min.* Nos. vi. and vii.

[**] See Ulloa's *Memoirs concerning America.*

Mercury has never been found in Britain, nor has any mine worth working been discovered in France.

The following Table exhibits a view of all the ores of this metal hitherto observed.

Table of the species.

I. Alloys
  1. Native
  2. Amalgam of silver
II. Sulphurets
  1. Cinnabar
  2. Hepatic ore
III. Salts
  1. Muriate

It is from the sulphuret that most of the mercury of commerce is extracted. Mercury occurs in two distinct formations; namely, in beds among rocks of clay slate, talc slate, and chlorite slate, in primitive mountains; and in the independent coal formation.

Genus I. Alloys.

Sp. 1. *Native Mercury*[*].

Native mercury is found in most mercurial mines; it is in small globules, scattered through different kinds of stones, clays, and ores.

Fluid. Colour tin white. Specific gravity about 13·6.

Sp. 2. *Amalgam of Silver*[†]—*Native Amalgam*.

This mineral has been found in the silver mine of

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[*] Brochant, ii. 96.—Hauy, iii. 423.—Jameson, ii. 113.

[†] Kirwan, ii. 223.—Brochant, ii. 99.—Hauy, iii. 432.—Jameson, ii. 116.

Alloys.

Salberg [*], in the province of Dalecarlia in Sweden; in the mines of Deux Ponts [†], in the Palatinate; and in other places. It is in thin plates, or grains, or crystallized in octahedrons and dodecahedrons.

Its colour is silvery white or grey. Fracture conchoidal. Lustre metallic. Creaks when cut. Very soft. Specific gravity above 10. Tinges gold white. Before the blow-pipe the mercury evaporates and leaves the silver.

Constituents.

A specimen of this amalgam, analysed by Klaproth, contained .... 64 mercury
36 silver

100 [‡]

According to Cordier,

72·5 mercury
27·5 silver

100·0 [§]

Sometimes it contains a mixture of alumina, and sometimes the proportion of mercury is so great that the amalgam is nearly as soft as paste.

Genus II. Sulphurets.

Sp. 1. *Native Cinnabar* [‖].

This ore, which is found in almost all mercurial mines, is sometimes in veins, sometimes disseminated,

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[*] Cronstedt's *Min.*

[†] Heyer, Crell's *Annals*, 1790.

[‡] *Beitrage*, i. 183.

[§] *Phil. Mag.* xiv. 41.

[‖] Kirwan, ii. 228.—Brochant, ii. 106.—Hauy, iii. 437.—Jameson, ii. 127.

sometimes in grains, and sometimes crystallized. It is divided into two subspecies, distinguished chiefly by their colour.

Subspecies 1. *Dark Red Cinnabar*. Colour cochineal red; sometimes falling into lead grey, sometimes passing into carmine red. Massive, disseminated, and crystallized in obtuse rhombs, six-sided tables, six-sided prisms, tetrahedrons, and octahedrons. Primitive form, according to Hauy, the regular six-sided prism. Internal lustre 3, 2, 1, adamantine. Fracture sometimes fine-grained uneven; sometimes even and conchoidal; also foliated. Fragments indeterminate, blunt-edged. Transparency of the massive 0, 1; of the crystals 2, 3. Streak scarlet red and shining. Very soft. Sectile. Frangibility 5. Specific gravity from 6·902 to 8·160.

Subspecies. 2. *Bright red Cinnabar*. Colour scarlet red. Massive and disseminated. Internal lustre 1; of the cross fracture 0. Fracture between earthy and fibrous; cross fracture earthy. Fragments indeterminate, blunt-edged. Opaque. Streak shining. Soils. Very soft. Sectile. Frangibility 5. Heavy.

Sp. 2. *Hepatic Ore* †.

This ore is divided into two subspecies, distinguished chiefly by their fracture.

Subspecies 1. *Compact Hepatic Ore*. This ore, which is the most common in the mines of Idria, is always

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* Rome de Lisle, iii. 154.

† Kirwan, ii. 224.—Brochant, ii. 104.—Jameson, i. 123.—Klaproth, Gehlen's *Jour*. v. 437.

amorphous, and is often mixed with native mercury and cinnabar. Found massive. Colour between dark cochineal and dark lead grey. Its streak cochineal red and shining. Fracture even. Opaque. Internal lustre 2, 1, semimetallic. Soft. Sectile. Frangibility 5. Specific gravity from 7·100 * to 7·186 †. When heated the mercury evaporates. It is insoluble in nitric, and soluble in muriatic acid ‡.

Subspecies 2. *Slaty Hepatic Ore.* Occurs in Idria, Almadin in Spain, and in Siberia. Colour as the preceding. Massive. Lustre of principal fracture 3; of cross fracture 1, semimetallic. Principal fracture curved thick slaty; cross fracture uneven. Fragments slaty. Frangibility 6. In other respects agrees with the preceding.

The following Table exhibits a view of the constituents of these species, according to the most recent analyses.

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* Klaproth. † Kirwan.

‡ See *Jour. de Phys.* xxiv. 61.

Constituents.

	Cinnabar.			Hepatic Ore.
	[*]	[†]	[‡]	[§]
Mercury	81·0	84·50	85·00	81·80
Sulphur	15·2	14·75	14·25	13·75
Charcoal				2·30
Silica				0·65
Alumina				0·55
Iron	4·7			0·20
Copper				0·02
Water				0·73
Loss		0·75	0·75	
	100·9	100	100	100

From this table, it appears that the hepatic ore consists chiefly of cinnabar, for the mercury and sulphur are in the same proportions nearly as in native cinnabar. The other ingredients are probably only mechanically mixed.

GENUS III. SALTS.

Sp. 1. *Muriate* [‖]—*Corneous Mercury.*

THIS ore was first discovered by Woulfe in the mines of the Palatinate: it has since been observed at Idria, Spain, and other places. Colour ash grey, which

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[*] Lampadius, *Handbuch zur Chem. Anal.* p. 260.

[†] From Japan. Klaproth, Gehlen's *Jour.* v. 435.

[‡] From Neumarktel. Klaproth, Ibid. p. 436.

[§] From Idria. Klaproth, Ibid. p. 440.

[‖] Scopoli, *Jour. de Min.* No. xxxvi. 919.—Kirwan, ii. 266.—Brochant, ii. 101.—Hauy, iii. 447.—Jameson, ii. 120.

passes into yellowish grey, greyish white, and sometimes inclines to greenish grey. Usually in small vesicles crystallized within. Crystals rectangular four-sided prisms, terminated by four-sided rhomboidal summits. Very small. Internal lustre 4, adamantine. Fracture straight foliated; sometimes in fine granular distinct concretions. Transparency 2, 1. Streak similar. Soft. Sectile. Frangibility 4. Volatilized before the blow-pipe.

Mr Woulfe discovered that this ore generally contains some sulphuric acid[*]. Specimens have been found in which the quantity of sulphuric acid exceeds that of the muriatic[†].

ORDER VI. ORES OF COPPER.

COPPER is one of the most generally distributed metals, and occurs in a great variety of states. It is found in almost every formation, but is more frequent in the newer primitive than in any of posterior date. It is most common in veins, but exists also abundantly in beds. The following Table exhibits a view of all the ores of this metal hitherto described:

Table of the Species.

I. ALLOYS.
    1. Native copper
II. SULPHURETS.
    1. Common sulphuret
    2. Variegated copper ore
    3. Copper pyrites
    4. White copper ore
    5. Grey copper ore
    6. Graugultigerz
    7. Black copper ore
III. OXIDES.
    1. Red copper ore

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[*] *Phil. Trans.* lxvi. 618.

[†] Suckow.

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2. Tile ore
3. Dioptase

IV. SALTS

1. Blue carbonate
2. Malachite
3. Mountain green
4. Iron shot mountain green
5. Arseniate
   Lamellar arseniate
   Lenticular
   Olive coloured
6. Muriate
7. Phosphate
8. Sulphate

GENUS I. ALLOYS.

Sp. 1. *Native Copper* *.

NATIVE copper occurs now and then in the greater number of copper mines: Sometimes it is in masses, sometimes in plates and threads, which assume a variety of forms; and sometimes, as in Siberia, it is crystallized in cubes, octahedrons, cubo-octahedrons, and six-sided prisms terminated by six-sided pyramids †, and in tetrahedrons.

Colour commonly that of copper, but sometimes dark brown. Lustre metallic. Streak brighter. Fracture hackly. Flexible and malleable. Hardness 6 to 7. Specific gravity from 7·6 ‡ to 8·5844 §.

GENUS II. SULPHURETS.

Sp. 1. *Common Sulphuret* ‖.

Vitreous Copper Ore—Copper Glance.

THIS ore occurs in veins and beds both in primitive

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* Kirwan, ii. 127.—Brochant, ii. 158.—Hauy, iii. 518.—Jameson, ii. 178.

† Hauy, *Jour. de Min.* No. xxxi. 509.

‡ Kirwan, *Miner.* ii. 128.

§ Hauy, *Jour. de Min.* No. xxxi. 509.

‖ Kirwan, ii. 144.—Brochant, ii. 162.—Hauy, ii. 551.—Jameson, ii. 183.

and floetz rocks. Werner divides it into two subspecies, distinguished chiefly by their fracture.

Subspecies 1. *Compact Sulphuret.* Colour dark lead grey, passing into blackish grey. Has often a tempered steel tarnish. Massive and disseminated, and rarely crystallized in cubes, six-sided prisms, double six-sided pyramids, and octahedrons. External lustre 3; internal 3, 2, metallic. Fracture small-grained uneven; passing into conchoidal. Fragments indeterminate, sharp-edged. Streak unaltered. Soft. Sectile. Frangibility 4. Specific gravity from 4·129 to 5·452 *.

Subspecies 2. *Foliated Sulphuret.* Colour as the preceding. Massive and disseminated. Has not been observed in crystals. Lustre of principal fracture 3; of cross fracture 1, metallic. Principal fracture pretty straight foliated with a single cleavage; cross fracture fine grained uneven. Fragments indeterminate, blunt-edged. Always in granular distinct concretions. In other characters agrees with the preceding.

This species before the blow-pipe melts easily; and while in fusion exhibits a green pearl, which, on cooling, is covered with a brown crust. Tinges borax green.

Sp. 2. *Variegated Copper Ore* †—*Buntkupfererz.*

This ore is found in masses, or plates, or disseminated; sometimes also it is said to be crystallized in octahedrons. Colour intermediate between copper red and pinchbeck brown; but when exposed to the air, it becomes first red, and then successively violet, azure, and

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* Kirwan.

† Kirwan, *Min.* ii. 142.—Brochant, ii. 166.—Hauy, iii. 56.—Jameson, ii. 189.

sky blue, and at last green; and all these colours appear often together. Internal lustre 3, 2, metallic. Fracture small imperfect conchoidal. Streak similar. Hardness 6 to 7. Specific gravity 4·956 to 4·983 *. Somewhat sectile. Frangibility 4.

Effervesces with nitric acid, and tinges it green. Deflagrates with nitre. Before the blow-pipe melts readily without smoke, vapour, or smell; but is not reduced. Tinges borax a bright green.

Sp. 3. *Copper Pyrites* †.

This is by far the most common of all the ores of copper. It occurs both in veins and beds in almost every formation. Found massive, or disseminated, or crystallized. The primitive form of its crystals is the tetrahedron; sometimes the angles are truncated; sometimes it is crystallized in octahedrons and dodecahedrons. Colour brass yellow, passing on the one hand to golden yellow, on the other to steel grey. Surface usually tarnished. Internal lustre 3, metallic. Fracture uneven. Soft; scarcely gives fire with steel. Brittle. Frangibility 4. Specific gravity 4·315. Before the blow-pipe on charcoal decrepitates, emits the odour of sulphur, and melts into a black globule, which gradually assumes the colour of copper. Tinges borax green.

Sp. 4. *White Copper Ore* ‡.

This species, first noticed by Henkel, is one of the

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* Kirwan.

† Kirwan, ii. 140.—Brochant, ii. 169.—Hauy, iii. 529.—Jameson, ii. 193.

‡ Kirwan, ii. 152.—Brochant, ii. 173.—Jameson, ii. 198.

rarest among the copper ores. It occurs in the primitive mountains, and has been observed in Cornwall, in different parts of Germany, &c. Colour between silver white and bronze yellow. The fracture soon acquires a greyish yellow tarnish. Massive and disseminated. Internal lustre 2, metallic. Fracture small-grained uneven. Soft, passing into semi-hard. Brittle. Frangibility 4. Specific gravity 4·500 *. Before the blow-pipe yields a white smoke, which has an arsenical smell, and then melts into a greyish black slag. Said to be composed of copper, iron, arsenic, and sulphur, and to contain about 40 *per cent.* of copper.

Sp. 5. *Grey Copper Ore* †—*Fahl Ore.*

This ore is found in Cornwall, Saxony, Hungary, &c. It occurs massive and disseminated, and often also crystallized. The primitive form of its crystals is the regular tetrahedron; but, in general, either the angles or the edges, or both, are truncated or bevelled ‡.

Colour steel grey; often tarnished, and then dark grey. Streak sometimes unaltered, sometimes reddish brown. Powder blackish; sometimes with a tint of red. Internal lustre 2, 3, metallic. Fracture coarse and small grained uneven; sometimes inclines to imperfect conchoidal. Hardness 7 or 8. Brittle. Specific gravity 4·8648 §. Deflagrates with nitre. Be-

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* Lametherie, as quoted by Jameson.

† Kirwan, ii. 146.—Klaproth's *Beitrage*, i. 177. and Gehlen's *Jour.* v. 3.—Brochant, ii. 175.—Hauy, iii. 537.—Jameson, ii. 201.

‡ Rome de L'isle, iii. 315. and Hauy's *Miner.* iii. 539.

§ Hauy, *Jour. de Min.* No. xxxi. 512.

fore the blow-pipe crackles, but at last melts, especially if assisted by borax. The bead gives a white smoke, without any particular smell ; tinges borax yellow or brownish red, but does not unite with it.

Sp. 6. *Graugiltigerz* *.

This species, first described and analysed by Klaproth, got its present name from that distinguished chemist, in consequence of the considerable proportion of silver which the first specimens examined contained ; but he afterwards found that this metal was only accidentally present in any notable quantity. It occurs at Cremnitz in Hungary, and in other places. Colour steel grey. Massive, and crystallized in tetrahedrons, seldom perfect, usually truncated in the edges or angles ; sometimes the tetrahedrons are double, constituting a hexahedron. Crystals small. Lustre 4, metallic. Fracture small conchoidal. Semihard. Brittle. From the preceding description †, it is obvious that this ore bears a strong resemblance to Fahl ore. It differs from it, however, in its composition.

Sp. 7. *Black Copper Ore* ‡.

This mineral is found on the surface and in rifts of other ores of copper, especially the other sulphurets. It is friable and often in powder. Colour between bluish and brownish black. Composed of dull dusty

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* Klaproth, *Beitrage*, i. 177. and Gehlen's *Jour.* v. 14.

† Karsten, Gehlen's *Jour.* v. 15.

‡ Kirwan, ii. 143.—Brochant, ii. 180.—Jameson, ii. 207.

Sulphurets.

particles, which scarcely soil. Heavy. Before the blow-pipe exhales a sulphureous odour. Tinges borax green. It contains about half its weight of copper. Originates probably from the decomposition of the other sulphurets.

The following Table exhibits a view of the constituents of such of the preceding ores as have been subjected to chemical analysis.

	Common Sulphuret.					Variegated Copper Ore.		Copper Pyrites.		Grey Copper Ore.				Graugultigerz.					
	*	†	†	‡	‖	§	§	¶	**	††	††	††	‡‡	§§	‖‖	‖‖	‖‖	‖‖	‖‖
Copper	78·5	74·5	47	76·5	73	58	69·5	41·0	30	41	48	42·5	19·2	31·36	37·75	39	40·25	37·5	26
Iron	2·25	1·5	9·3	0·5	1	18	7·5	17 1	31	22 5	25·5	27·5	51	3·3	3·25	7·5	13·5	6·5	7·0
Arsenic										24 1	14	15·6	15·7				0·75		
Antimony												1·5		34·09	22	19·5	23	29	27
Silver										0·4	0·5	0·9		14·77	0·25		0·3	3	13·25
Sulphur	18·5	20·5	13	22	24·5	19	19	45·1	36·5	10	10	10	14·1	11·5	28	26	18·5	21·5	25·5
Oxygen						5	4												
Zinc									1						5				
Mercury																6·25			
Silica	0·75		25		1·28														
Alumina														0·3					
Lime			7																
Earthy mat.									1										
Loss		3·5		1	0 22				0·5	2	2	2		4·68	3·75	1·75	3·7	2·5	1·25
	100	00	101·3	100	100	100	00	103·2	100	100	100	100	100	100	00	100	100	100	100

* Klaproth, *Beitrage*, ii. 279.

† Gueniveau, Nicholson's *Jour*. xxi. 145.

‡ Klaproth, *Beitrage*, iv. 37.

‖ By my analysis. The specimen was from Nova Scotia.

§ Klaproth, *Beitrage*, ii. p. 283 and 286.

¶ Lampadius, *Handbuch*, p. 263.

** Gueniveau, Nicholson's *Jour*. xxi. 146.

†† From Freyberg. Klaproth, Gehlen's *Jour*. v. 9. 11. and 13.

‡‡ From Airthrey near Stirling. By my analysis, *Trans. Edin*. vi. 264. It contained iron and arsenical pyrites which could not be completely separated. Hence probably the small proportion of copper compared with that obtained by Klaproth.

§§ Klaproth, *Beitrage*, i. 180.

‖‖ Klaproth, Gehlen's *Jour*. v. 20. 23. 25. 28. and 30.

Oxides.

From this table, it appears probable that the common sulphuret consists essentially of copper and sulphur. In the variegated copper ore iron is also present, and the copper seems to be in the state of protoxide; copper pyrites contains also iron, but the sulphur exists in it in a much greater proportion than in the preceding. Grey copper ore appears to be a compound of copper, iron, arsenic, and sulphur; the constituents of graugultigerz are the same, except that antimony is substituted in place of arsenic.

GENUS III. OXIDES.

Sp. 1. *Red Copper Ore*[*].

THIS ore seems to be peculiar to the primitive mountains. It is most common in veins, and is found in Cornwall, various parts of Germany, Sweden, &c. It has been subdivided into three subspecies, distinguished chiefly by their fracture.

Subspecies 1. *Compact*. Colour dark cochineal red, inclining a little to lead grey. Massive and disseminated. Internal lustre 1, 2, semimetallic. Fracture even. Opaque. Hardly ever in distinct concretions. Streak tile red, and of diminished lustre. Semihard. Brittle. Frangibility 4. Heavy.

Subspecies 2. *Foliated*. Colour as the preceding. Crystals are redder, and sometimes pass into dark carmine red. Massive, disseminated, and crystallized in cubes and octahedrons which are often truncated. Internal lustre 3, 2, adamantine. Fracture imperfect fo-

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[*] Kirwan, ii. 135.—Brochant, ii. 181.—Hauy, iii. 555.—Jameson, ii. 209.

liated. Very seldom in granular distinct concretions. Transparency of the massive 0; of the crystals 4 to 2. Streak dirty tile red. Semihard. Brittle. Frangibility 4. Specific gravity 3·950.

Subspecies 3. *Capillary.* Colour carmine red, sometimes approaching cochineal red. In small capillary crystals, and in tables. Lustre 3, adamantine. Transparency 2.

Red copper ore is soluble with effervescence in nitric acid, and in muriatic acid without effervescence. Before the blow-pipe melts easily, and is reduced.

Sp. 2. *Tile Ore*[*].

This mineral occurs in veins, and is divided into two subspecies; namely, *earthy* and *indurated tile ore.*

Subspecies 1. *Earthy.* Colour hyacinth red, sometimes brownish red. Between friable and solid. Massive, disseminated, and incrusting copper pyrites. Composed of dull dusty particles. Soils slightly. Heavy.

Subspecies 2. *Indurated.* Colour between hyacinth and brownish red, passing into lead grey and blackish brown. Massive and disseminated. Internal lustre 1. Fracture between even and large conchoidal, and sometimes passes into small conchoidal. Semihard. Rather brittle. Frangibility 4. Heavy.

Infusible before the blow-pipe, but acquires a black colour.

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[*] Kirwan, ii. 137.—Brochant, ii. 187.—Jameson, ii. 214.

Sp. 3. *Dioptase**.—*Copper Emerald.*

This mineral, which at first was confounded with the emerald, is found in the north of Asia. Colour emerald green. Crystallized in six-sided prisms terminated by three-sided pyramids. Primitive form of the crystals an obtuse rhomboid. Lusture 3, vitreous. Fracture foliated with a threefold cleavage. Fragments indeterminate, blunt-edged. Transparency 2, 3. Scratches glass with difficulty. Brittle. Specific gravity 3·3 †. Before the blow-pipe becomes chesnut brown, but is infusible. Tinges the flame green.

Red copper ore, according to the analysis of Chenevix and Klaproth ‡, consists entirely, when pure, of protoxide of copper. Tile ore has not been analysed; but is supposed to be merely an intimate mixture of red copper ore and iron ochre. In the dioptase the copper is in the state of peroxide. The constituents of this mineral, as ascertained by Vauquelin, are as follows:

Oxide of copper.........	28·57
Carbonate of lime......	42·85
Silica.....................	28·57
	99·99 §

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* Hauy, ii. 136.—Brochant, ii. 511.—Jameson, ii. 241.

† Hauy.

‡ *Beitrage*, iv. 27.

§ Hauy, iii. 137.

GENUS IV. SALTS.

Sp. 1. *Blue Carbonate of Copper*[*].

Mountain blue—Azur de cuivre—Blue calx of Copper—Kupfer-lazur—Copper azure.

THIS ore, which occurs in the copper mines of Siberia, Sweden, Germany, Hungary, Britain, &c. is more common in the floetz than in the primitive mountains. It is divided into two subspecies.

Subspecies 1. *Earthy.* Colour smalt blue. Usually friable; seldom massive. Composed of dull dusty particles. Scarcely soils. Approaching heavy.

Subspecies 2. *Radiated.* Principal colour azure blue. Occurs also berlin blue, and sometimes inclines to smalt blue. The colours have a slight tint of red. Seldom massive; more frequently botryoidal and stalactitic; most frequently crystallized. The crystals are small, and difficult to examine. Their primitive form is an octahedron, the sides of which are scalene triangles, and two of them more inclined than the others. The crystals are often rhomboidal prisms, terminated by four-sided summits. The edges are often variously truncated[†]. Internal lustre 3, 2, between vitreous and resinous. Fracture narrow, straight, and scopiform radiated; sometimes imperfect foliated. Seldom in granular distinct concretions. Transparency of the crystals, 2, 3. Streak similar. Soft. Rather brittle. Specific gravity 3·608[‡]. It effervesces with nitric acid.

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[*] Kirwan, ii. 129.—Morveau, *Mem. Dijon*, 1782. 1. Semestre, p. 100. —Brochant, ii. 190.—Hauy, iii. 562.—Jameson, ii. 218.

[†] Rome de Lisle observed, that the crystals obtained from the solution of copper in ammonia have the same forms with those of this ore; and this observation has been confirmed by Hauy.

[‡] Brisson.

and gives it a blue colour. Before the blow-pipe it blackens, but does not melt. Tinges borax green with effervescence.

Sp. 2. *Malachite* *.

This ore occurs in the newer primitive and in the floetz mountains. It has been divided into two subspecies, distinguished by the fracture.

Subspecies 1. *Fibrous.* Colour emerald green; sometimes inclines to grass green, sometimes to dark leek green. Seldom massive; sometimes disseminated, and often crystallized in short capillary prisms. Internal lustre 3, 1, silky. Fracture usually very delicate fibrous; sometimes coarse fibrous. Fragments wedge-shaped and splintery. Occurs in granular distinct concretions. Transparency of the crystals 2; of the massive 1. Soft. Streak lighter. Approaching sectile. Specific gravity 3·571 †.

Subspecies 2. *Compact.* Colour emerald green, inclining to verdegris green. Often tarnished greenish white, and is marked with stripes of a darker colour. Massive, in various particular shapes, and crystallized in four-sided prisms terminated by four-sided pyramids. Internal lustre 3, 2, 1, silky. Fracture sometimes very delicate fibrous, which passes into even; this into flat and small conchoidal, which sometimes passes into small-grained uneven. Fragments indeterminate. Usually in thin lamellar distinct concretions; surface of the concretions rough, and covered with a thin green

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* Kirwan, ii. 131.—Fontana, *Jour. de Phys.* xi. 509.—Klaproth's *Beitrage*, ii. 287.—Brochant, ii. 197.—Hauy, iii. 571.—Jameson, iii. 226.

† Brisson.

film. Opaque. Soft. Not particularly brittle. Frangibility 5. Streak similar. Specific gravity 3·683 *.

Before the blow-pipe it decrepitates and blackens, but does not melt. Tinges borax yellowish green, Tinges flame green.

Sp. 3. *Mountain Green* †.

Found in the same situations as the preceding species. Colour verdegris green; sometimes passing into emerald green, and sometimes inclining to leek green. Massive; disseminated, and botryoidal. Internal lustre 3, 2, resinous. Fracture small conchoidal. Fragments indeterminate, more or less sharp-edged. Never in distinct concretions. Transparency 2, 3, 1. Soft. Not particularly brittle. Frangibility 4. Moderately heavy. Blackens before the blow-pipe, but does not melt. Dissolves in acids with scarcely any effervescence.

Sp. 4. *Iron Shot Mountain Green* ‡.

This species is usually accompanied by the two preceding. It is divided into two subspecies.

Subspecies 1. *Earthy.* Colour olive green; sometimes passing into pistachio green. Massive and disseminated. Dull. Fracture earthy. Soils a little. Fragments indeterminate, blunt-edged. Opaque. Streak nearly similar. Very soft. Frangibility 4.

Subspecies 2. *Slaggy.* Colour dark olive and pistachio green, which passes into dark blackish green. Massive and disseminated. Internal lustre 3, 2, resi-

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* Kirwan.

† Kirwan, ii. 134.—Brochant, ii. 203.—Jameson, ii. 233.

‡ Kirwan, ii. 151.—Brochant, ii. 205.—Jameson, ii. 237

Salts.

nous. Fracture small conchoidal. Fragments indeterminate, more or less sharp-edged. Opaque. Streak paler. Soft. Frangibility 4.

Sp. 5. Arseniate of Copper.

Hitherto this species has been found only in Cornwall. It was discovered above 20 years ago in the Carrarach mine; but it had become exceedingly scarce, till it was lately found in abundance in the Huel Garland mine. A great variety of specimens were carried to London; and they have been admirably described and analysed by the Count de Bournon and Mr Chenevix *. It has been divided into three subspecies, distinguished chiefly by the figure of their crystals.

Subspecies 1. *Foliated Arseniate* †.—*Copper Mica.* Colour emerald green. Massive, disseminated, and sometimes crystallized. Crystals thin hexahedral laminæ; the six faces inclined alternately towards the opposite sides of the plates, so that three lie one way and three another. Two of these three are inclined at angles of 135°; the other at an angle of 115°. Divisible into thin plates like mica. Lustre 4, pearly. Fragments indeterminate and tabular. In granular distinct concretions. Transparency of the massive 2; of the crystals 4. Scratches gypsum, but not calcareous spar. Sectile. Specific gravity 2·548. Decrepitates when heated.

Subspecies 2. *Lenticular Arseniate* ‡. Colour sky blue, which sometimes passes into verdegris green.

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* *Phil. Trans.* 1801, p. 169.

† Bournon, *Phil. Trans.* 1801.—Jameson, ii. 243.

‡ Bournon, Ibid.—Jameson, ii. 245.

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Crystallized in obtuse octahedrons, composed of two four-sided pyramids with isosceles triangular faces, two of which are more inclined than the other two. The two most inclined meet at the apex at an angle of 130°, and form at the base angles of 50°: the two least inclined meet at the apex in an angle of 115°, and form at the base angles of 65°. Sometimes the apex is converted into a ridge; the octahedron being lengthened parallel to the less inclined planes. External lustre 3. Fracture foliated. Transparency 2. Scratches calcareous spar, but not fluor spar. Rather brittle. Frangibility 6. Specific gravity 2·882.

Subspecies 3. *Oliven Ore**. Of this subspecies two varieties have been distinguished.

1. Foliated. Colour perfect olive green; sometimes inclining to oil green and leek green. Seldom massive; usually in drusy crusts; and crystallized in very acute rhomboids, sometimes having their angles truncated. Faces of the crystals smooth; lustre 3, 4. Internal lustre 2, 3, adamantine. Fracture imperfect foliated. Fragments indeterminate. The massive varieties occur in granular distinct concretions. Transparency 2, 3. Streak straw yellow. Very soft. Sectile. Specific gravity 4·2809.

2. Fibrous. Colour olive green. Massive. Varieties pass into liver brown and into greenish white. Massive, reniform, and crystallized in acicular four-sided prisms. Internal lustre 2, adamantine. Fracture delicate scopiform fibrous. Fragments wedge-shaped;

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* Kirwan, ii. 151.—Brochant, ii. 208.—Hauy, iii. 575.—Bournon and Chenevix, *Phil. Trans.* 1801.—Klaproth, iii. 187.—Jameson, ii. 245.

sometimes in coarse granular, and in curved lamellar distinct concretions. Transparency 1 sometimes scratches fluor spar. Rather brittle. Specific gravity 4·281.

Sp. 6. *Muriate of Copper**—*Green-Sand of Peru.*

This ore, which was brought from Peru by Dombey, is a green powder mixed with grains of quartz. When thrown on burning coals, it communicates a green colour to the flame. It is soluble both in nitric and muriatic acids without effervescence. The solution is green. This mineral was first proved to contain muriatic acid by Berthollet†. Afterwards Proust analysed it ‡; but Vauquelin announced that he considered it merely as an oxide of copper mixed with common salt §. However, a subsequent examination convinced him that his opinion was unfounded; and that the mineral was really a muriate, as had been affirmed by Berthollet and Proust ‖. This conclusion has been confirmed by Klaproth.

Colour sometimes between leek and emerald green; sometimes between emerald and olive. Massive and crystallized in flat six-sided prisms, bevelled at the extremities, and in oblique four-sided prisms. Surface smooth; lustre 4, adamantine. Internal lustre 3, resinous. Fracture foliated. Massive. Opaque. Crystals transparent. Soft. Streak pale apple green. Rather sectile. Frangibility 4. Specific gravity 3·570 **.

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* Kirwan, ii. 149.—Brochant, ii. 545.—Hauy, iii. 560.—Jameson, ii. 572.

† *Mem. Par.* 1786, p. 4 and 62.

‡ *Ann. de Chim.* xxxii. 26.

§ *Jour. de Min.* No. xxxi. 519.

‖ Hauy, iii. 562.

** Lametherie.

Sp. 7. *Phosphate of Copper*[*].

This ore has been found at Rheinbreiderbach near Cologne, and was considered as a variety of malachite, till Klaproth ascertained its composition. Found massive, disseminated, and crystallized in small oblique hexahedrons. They occur in groups, often so small as to resemble moss. Colour externally greyish black; but within, between verdegris and emerald green. External lustre 4, vitreous; internal 1, silky. Fracture fibrous; fibres diverging. Opaque. Streak apple green. Sectile. Soft.

Sp. 8. *Sulphate of Copper*.

This salt occurs occasionally in the neighbourhood of copper mines, either massive, in particular shapes, or in capillary and cubic crystals. Its properties have been already detailed in the First Part of this Work.

The following Table exhibits a view of the constituents of such of the preceding species as have been analysed:

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[*] Klaproth, iii. 201.—Brochant, ii. 544. Jameson, ii. 574.

Salts.
Constituents.

	Blue Carbonate.		Malachite.	Mountain Green.	Foliated Arseniate.		Lenticular Arseniate.	Oliven Ore.					Arseniate.		Muriate.			Phosphate.
	†	‡	§	‖	**	¶	**	**	**	**	**	††	‡‡	‡‡	§§	§§	‖‖	¶¶
Ox. of copper	77	70	70·5	50	58	39	50		60	51	50	50·62	26	28	76·6	70·5	73	68·13
Carbonic acid	19	24	18	7														
Arsenic acid					21	43	14·3	30	39·7	29	29	45	69	72				
Muriatic acid															10·6	11·4	10·1	
Phosphor. acid																		30·95
Silica				26														
Water	2	6	11·5	17	21	17	35·7	16		18	21	3·5			12·8	18·1	16·9	
Loss	2					1			0·3	2		0·88	5					0·92
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

[†] Pelletier, *Ann. de Chim.* xiii. 54.

[‡] Klaproth, *Beitrage*, iv. 31. The specimen analysed was from Siberia, and belonged to the radiated subspecies.

[§] Ibid. ii. 290.

[‖] Ibid. iv. 34. From Siberia.

[**] Chenevix, *Phil. Trans.* 1801, p. 207.

[¶] Vauquelin.

[††] Klaproth.

[‡‡] This is the result stated in the Philosophical Magazine (Vol. xxxiii. p. 332.), to have been obtained by Mr Gregor from the analysis of two specimens of native arseniate of copper from Cornwall of a pale yellow colour. Unless there be some mistake in the account, they must have belonged to a subspecies very different from any known before.

[§§] Proust, *Ann. de Chim.* xxxii. 49.

[‖‖] Klaproth, iii. 200.

[¶¶] Ibid. p. 201.

ORDER VII. ORES OF IRON.

IRON is the most abundant of metals; it exists in every formation, and assumes the most different and even opposite shapes. This renders it a more difficult task to bring its ores under a regular arrangement than those of any other metal. The following Table exhibits a view of the different ores of this metal, arranged according to their component parts;

Table of the species.

I. ALLOYS
- 1. Native iron

II. SULPHURETS
- 1. Iron pyrites
- 2. Magnetic pyrites

III. OXIDES
- 1. Magnetic iron ore
- 2. Specular iron ore
- 3. Red ore
- 4. Brown ore
- 5. Sparry iron ore
- 6. Black ore
- 7. Yenite
- 8. Clay ironstone ore
- 9. Bog ore

IV. SALTS
- 1. Carbonate
- 2. Phosphate
- 3. Blue iron earth
- 4. Phosphate of iron and manganese
- 5 Arseniate
- 6. Chromate
- 7. Sulphate
- 8. Tungstate

GENUS I. ALLOYS.

Sp. 1. *Native Iron.*

This mineral is rare, but it has been observed in different parts of the world. A specimen, weighing about 4 lbs. was found in the mine of Hackenberg *. Colour

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* Cramer, *Phil. Mag.* xiii. 32.

bluish white. Fracture hackly. Lustre metallic. Malleable. Magnetic. Hardness 8 to 9. Specific gravity 7·8. The masses of iron observed by Pallas in Siberia, by Rubin de Celis in South America, &c. are now considered as depositions from meteors. They are distinguished from native iron by containing nickel, of which the true specimens of native iron are destitute. A specimen of native iron from the mine Johannes, near Kamsdorf in Saxony, analysed by Klaproth, contained

92·5	iron
6·0	lead
1·5	copper
100·0 *	

GENUS II. SULPHURETS.

Sp. 1. *Iron Pyrites* †.

THIS mineral is one of the most abundant in nature, occurring in almost every rock and vein. Its forms, too, are equally varied. It is massive, disseminated, globular, oviform, &c. and very often crystallized. The most common figures of its crystals are the cube, the octahedron, the rhomboidal dodecahedron, and the icosahedron; but the angles and edges are often variously truncated. The cubes are sometimes smooth and sometimes striated: the striæ are parallel to the edges of the faces, and in three different directions. Romé de Lisle showed, that its primitive form was sometimes

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* Gehlen's *Jour.* i. 36.

† Kirwan, ii. 76.—Brochant, ii. 221.—Hauy, iv. 65.—Bournon, *Jour. de Min.* No. lxxv. 170.—Jameson, ii. 253.

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a cube and sometimes an octahedron. Hauy considers the cube as the primitive form. But when we attempt to ascertain the natural joints of the crystals, we, in some cases, obtain a cube, in others an octahedron. Hence Bournon considers these two forms as distinct, and constituting two species of pyrites; which he thinks chemical analysis will one day demonstrate to differ in their composition. The striated cubes, according to him, constitute a third species. For a description and figure of the different crystals of this mineral, the reader may consult Romé de Lisle *, Hauy †, and Bournon ‡. Werner divides it into five subspecies, and even these scarcely include all the varieties of this mineral which have been observed.

Subspecies 1. *Common Pyrites.* Colour bronze yellow. Massive and crystallized in cubes, either perfect or truncated, in octahedrons, dodecahedrons, and even icosahedrons. Surface sometimes smooth, sometimes streaked. Lustre from 4 to 2, metallic. Fracture uneven. Hard. Brittle. Frangibility 3. Specific gravity 4·830 §.

Subspecies 2. *Radiated Pyrites.* Colour bronze yellow; sometimes inclining to brass yellow. Surface tarnished. Massive, reniform, and crystallized in octahedrons, either perfect or truncated, and in cubo-octahedrons. External lustre from 3 to 1. Fracture radiated. Passes into fibrous and into compact. Fragments wedge-shaped. In granular, lamellar, and columnar distinct concretions. Hard. Brittle. Frangibility 6. Specific gravity from 4·698 to 4·775 ||.

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* *Crystallog.* iii. 208.

† *Miner.* iv. 67.

‡ *Jour. de Min.* No. lxxv. 170.

§ Hatchett.

|| Ibid.

Sulphurets.

Subspecies 3. *Hepatic Pyrites.* Colour pale brass yellow, inclining to steel grey. Fresh fracture becomes brown when exposed. Massive, tuberose, &c. and crystallized in tetrahedrons and six-sided prisms. Internal lustre 1, 2, metallic. Fracture usually even. Fragments indeterminate, sharp-edged. In distinct concretions. In other respects the same as the preceding. Very subject to decomposition.

Subspecies 4. *Capillary Pyrites.* Colour dark bronze yellow, which sometimes passes into steel grey. In very delicate capillary crystals. Lustre metallic. Brittle. Slightly flexible.

Subspecies 5. *Cellular Pyrites.* Colour bronze yellow, inclining very much to steel grey, and a little to green. Acquires a grey tarnish. Massive, but most frequently cellular. Surface of the cells drusy. Internal lustre 1. Fracture even and flat conchoidal. Fragments indeterminate, pretty sharp-edged. In other characters agrees with the preceding.

Sp. 2. *Magnetic Pyrites* *.

This occurs only in the primitive mountains, and has hitherto been observed only in beds. Colour between bronze yellow and copper red, and sometimes inclines to pinchbeck brown. Acquires a brownish tarnish. Massive and disseminated. Internal lustre 3, 2, metallic. Fracture uneven. Fragments indeterminate, blunt-edged. Never in distinct concretion. From hard to semihard. Brittle. Frangibility 4. Specific gravity 4·518 †. Attracted by the magnet.

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* Kirwan, ii. 79.—Brochant, ii. 232.—Jameson, ii. 265.

† Hatchett.

From the analysis of Hatchett it has been ascertained, that the first of the preceding species is a supersulphuret, and the second a common sulphuret of iron; and that some of the subspecies of the first species differ a very little from each other in the proportion, and probably in the state, of the sulphur *.

Genus III. Oxides.

Sp. 1. *Magnetic Iron-Stone* †—*Fer Oxidulé* of Hauy.

This species, characterized in some measure by its magnetic properties, is divided by Werner into two subspecies.

Subspecies 1. *Common Magnetic Iron-Stone.* This ore occurs most frequently in primitive mountains, and usually in gneiss, mica slate, chlorite slate, and primitive lime-stone; but sometimes also in rocks of the floetz trap formation. It is found in beds, and sometimes composes whole mountains. It is very common in Sweden; it is found also in Switzerland, Norway, Russia, &c. It occurs massive, in plates, grains, and crystallized. The primitive form of its crystals is a regular octahedron ‡. Sometimes two opposite sides of the pyramids are trapeziums, which renders the apex of the pyramids cuneiform; sometimes in cubes; sometimes the crystals pass into rhomboidal parallelopipeds, and into dodecahedrons with rhomboidal faces §.

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* See the result of the analysis of this celebrated chemist in Vol. I. p. 230 of this Work.

† Kirwan, ii. 158.—Brochant, ii. 235.—Hauy, iv. 10.—Jameson, ii. 269.

‡ Romé de Lisle, iii. 178.

§ Ibid.

Colour iron black. Powder black[*]. Streak unaltered. External lustre 3; internal 3, 2, metallic. Fracture uneven; sometimes approaches even, also imperfect straight foliated. Hardness 9 to 10. Sometimes in granular distinct concretions. Brittle. Specific gravity from 4·200 to 4·939[†]. Attracted by the magnet, and generally possessed of more or less magnetic virtue[‡]. To this species belongs the magnet. Before the blow-pipe it becomes browner, but does not melt. Tinges borax dark green. By the analysis of Bucholz, this ore is composed of a mixture of two distinct oxides of iron and a little quartz[§].

Subspecies 2. *Iron-Sand.* Occurs imbedded in basalt and wacke, and in the sand of rivers. Colour dark iron black. In small angular and roundish grains, and in octahedral crystals. Surface rough and feebly glimmering. Internal lustre 3, 4, metallic. Fracture perfect conchoidal; very rarely imperfect foliated. Fragments indeterminate, sharp-edged. Semihard. Brittle. Frangibility 4. Specific gravity 4·600[‖]. Strongly attracted by the magnet.

Sp. 2. *Specular Iron Ore*[¶].

Iron Glance—Fer Oligiste.

This ore appears to be confined to the primitive and transition mountains. It occurs both in veins and beds. It is divided into two subspecies.

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[*] Hauy, *Jour. de Min.* No. xxxiii 659.

[†] Kirwan's *Min.* ii. 159.

[‡] Hauy, *Jour. de Min.* No. xxxi. 527.

[§] Gehlen's *Jour.* Second Series, iii. 106.

[‖] Kirwan.

[¶] Kirwan, ii. 162.—Coudrai, *Jour. de Phys.* iv. 52.—Brochant, ii. 142.—Hauy, iv. 38.—Jameson, ii. 276.

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Subspecies 1. *Common.* This ore is found abundantly in the isle of Elba near Tuscany, in Germany, France, Russia, &c. It is either in masses or crystallized. The primitive form of its crystals is a rhomboid, which differs very little from a cube; the angles of the rhombs being 87° and 93°. It occurs in a variety of forms: The most common are the rhomboidal parallelopiped; the cube, with three triangular faces instead of two of its angles diagonally opposite; two six-sided pyramids, applied base to base, wanting the summits, and sometimes the angles at the bases, and sometimes the alternate edges of the pyramid; a polyhedron of 24 sides, resembling a cube with three triangular faces for two angles diagonally opposite, and two triangles for the rest of its angles; thin octagonal plates, bounded by six linear trapeziums, alternately inclined different ways.

Colour steel grey; often tarnished, and beautifully iridescent, reflecting yellow, blue, red. Streak cherry red. Powder blackish red. External lustre 4 to 2; internal 2, 3, metallic. Hardness 9 to 10. Fracture sometimes compact, sometimes foliated. The compact is uneven, and sometimes passes into imperfect small conchoidal; the foliated has a fourfold rectangular cleavage. Fragments octahedral or pyramidal; sometimes indeterminate; usually unseparated. Frangibility 2. Brittle. Specific gravity 5·0116* to 5·218†. Slightly magnetic. Does not attract iron filings, as is the case with the last species. Little altered by the blow-pipe. Tinges borax an obscure yellow.

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* Brisson.

† Kirwan.

Subspecies 2. *Micaceous Iron Ore—Iron mica.* Occurs in Perthshire and other parts of Scotland, &c. Colour iron black. The thin plates, when held between the eye and the light, appear blood red. Massive, and crystallized in thin six-sided tables. Surface of the crystals smooth and splendent. Internal lustre 4, 3, metallic. Fracture perfect curve-foliated. Cleavage single. Fragments sometimes indeterminate; sometimes tabular. The massive occurs in granular distinct concretions. Transparency 1; in thin plates 2. Streak cherry red. Semihard. Brittle. Frangibility 6. Specific gravity 3·50 to 5·07 *. According to the analysis of Bucholz this subspecies consists entirely of peroxide of iron †.

Oxides.

Sp. 3. *Red Iron-Stone* ‡.

This is one of the most common iron ores. It occurs in great abundance in Lancashire, and in different parts of Germany; but scarcely in Russia, Sweden, Norway, Poland, or Hungary §. It is found both in beds and veins, and both in the primitive and floetz mountains.

Colour red. Streak blood red. Specific gravity from 2·952 to 5·005. Before the blow-pipe blackens, but does not melt. Tinges borax yellowish olive green. When digested in ammonia, it becomes black, and often magnetic. It is usually divided into four subspecies.

Subspecies 1. *Red Scaly Iron Ore—Eisenrham—Iron*

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* Kirwan.

† Gehlen's *Jour.* Second Series, iii. 104.

‡ Kirwan, ii. 158.—Brochant, ii. 249.—Jameson, ii. 285.

§ Jameson, ii. 295.

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Froth. Colour between cherry and brownish red, often passing into steel grey. Usually friable. Lustre 1, semimetallic. Feels greasy. Hardness 3 to 4. Brittle. Moderately heavy. Composed of scaly friable parts, which soil strongly. This subspecies is rare ; it occurs in different parts of Germany and Hungary and Britain.

Subspecies 2. *Red Ochre.* Found sometimes in powder, sometimes indurated. Composed of dusty particles, which have a faint glimmering lustre. Colour light blood red. Soils. Feels meagre. Not particularly brittle. Specific gravity 2·952. Hardness 3 to 5. Accompanies the other subspecies.

Subspecies 3. *Compact.* Found massive and disseminated, and in various imitative forms; sometimes crystallized in cubes or four-sided pyramids, having their apex truncated. Colour between brown red and steel grey. Fracture usually even, rarely passes into coarse-grained uneven, large conchoidal and slaty. Lustre 1, semimetallic. Hardness 7 to 9. Not particularly brittle. Specific gravity 3·423 to 3·76 *. Sometimes invested with a rosy red ochre. Found abundantly in Germany, France, &c.

Subspecies 4. *Red Hæmatites.* Found in masses, and all the variety of forms of stalactites, in kidney form balls, &c. Colour between brownish red and steel grey. Powder red. Internal lustre 1 to 2, semimetallic. Fracture fibrous. Fragments usually splintery or wedge-shaped. In angular granular distinct concre-

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* Kirwan.

tions. Hardness 9 to 10. Brittle. Frangibility 3. Specific gravity 4·74[*] to 5·005[†].

Sp. 4. *Brown Iron-Stone*[‡].

This ore is found in the newest primitive mountains, but more frequently in the transition and floetz. It occurs in veins, beds, and mountain masses. In Russia, Sweden, and Norway, it is scarcely found. In Britain, it has been observed in small quantity in Cornwall, and in one of the Shetlands; but it abounds in Germany, France, and Italy[§]. Colour brown. Streak brown or ochre yellow. It is divided into four subspecies.

Subspecies 1. *Brown Scaly Iron Ore—Brown Iron Froth*. This subspecies is generally incumbent on other minerals. Colour between clove brown and steel grey. Between friable and solid. Massive, coating, and frothy. Composed of scaly particles. Lustre 3, 2, metallic. Soils strongly. Feels greasy. Hardness 3 to 5. So light as often to float on water.

Subspecies 2. *Ochry Brown Iron-Stone*. It occurs both massive and disseminated. Colour very light yellowish brown. Between solid and friable. Composed of coarse earthy particles, dull or faintly glimmering. Soils strongly. Hardness 3 to 4. Between brittle and sectile. When slightly heated reddens. Accompanies the other subspecies.

Subspecies 3. *Compact Brown Iron-stone*—This subspecies occurs in masses of very various, and often

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[*] Gellert. [†] Kirwan.

[‡] Kirwan, ii. 163.—Brochant, ii. 257.—Jameson, ii. 296.

[§] Jameson, ii. 307.

fantastical shapes; sometimes in pseudo-crystals. Colour clove brown. Internal lustre 1, semimetallic. Fracture commonly even. Fragments indeterminate, blunt-edged. Streak yellowish brown. Frangibility 4. Hardness 6 to 9. Brittle. Specific gravity 3·4771[*] to 3·752[†].

Subspecies 4. *Brown Hæmatites.* The name hæmatites (bloodstone) was probably applied by the ancients to those ores only which are of a red colour, and have some resemblance to clotted blood; but by the moderns it is applied to all the ores of iron which give a reddish-coloured powder, provided they be of a fibrous texture.

Brown hæmatites occurs rarely massive, usually in imitative forms of various kinds, and sometimes in pseudo-crystals, consisting of six-sided acute angled pyramids. Colour clove brown; sometimes passing into steel grey, bluish brown or ochre yellow; sometimes iridescent. External lustre 4; internal 2, between silky and resinous. Fracture fibrous. Fragments splintery, wedge-shaped, indeterminate. In granular distinct concretions. Hardness 8 to 10. Brittle. Opaque. Specific gravity 3·789[‡] to 3·951[§]. Not magnetic. Streak ochre yellow.

Sp. 5. *Sparry Iron Ore*[‖].

This ore is common in Germany, France, and Spain, and occurs in small quantities in Britain. It is found

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[*] Brisson. [†] Kirwan. [‡] Gellert. [§] Kirwan.

[‖] Kirwan, ii. 190.—Bergman, ii. 184.—Bayen, *Jour. de Phys.* vii. 213.—Razowmoski, *Mem. Lausanne*, 1783, p. 149.—Brochant, ii. 264.—Jameson, ii. 308.

sometimes in amorphous masses, and sometimes crystallized in rhombs, lenses, octahedrons, and dodecahedrons.

Colour light yellowish grey, passing into yellowish brown and blackish brown. Sometimes intermediate between yellowish brown and greenish grey. On exposure to the air or heat the colours change into brown or black. Internal lustre from 4 to 1, pearly. Fracture more or less perfect foliated. Cleavage threefold. Fragments rhombs like those of calcareous spar. Transparency 1, 2, 0. In granular distinct concretions. Streak yellowish brown. Harder than calcareous spar. Not particularly brittle. Frangibility 4. Specific gravity 3·640 to 3·810 *. Becomes black before the blow-pipe.

Sp. 6. *Black Iron-Stone* †.

This ore, which occurs both in primitive and floetz mountains, was long confounded with grey ore of manganese, and was first accurately discriminated by Werner. It is a rare mineral. I have specimens of the first subspecies from the neighbourhood of Paisley. It is divided into two subspecies.

Subspecies 1. *Compact Black Iron-Stone.* Usually massive; often in various imitative forms. Colour between steel grey and bluish black. Internal luster 1, 2, semimetallic. Fracture usually conchoidal; sometimes passing into uneven. Fragments indeterminate, sharp-edged. Streak shining, but no change of colour.

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* Kirwan.

† Kirwan, ii. 167.—Brochant, ii. 268.—Jameson, ii. 313.

Brittle. Hardness 7. Frangibility 4. Specific gravity 4·076.

Subspecies 2. *Black Hæmatites.* Colour inclines more to steel grey than the preceding. Massive and reniform. Internal lustre 1, 2, semimetallic. Fracture delicate fibrous, passing into even. Fragments wedge-shaped. In coarse granular distinct concretions. Streak shining. In other characters agrees with the preceding.

Sp. 7. *Yenite* *.

This mineral was discovered, and brought from the isle of Elba by Mr Le Lievre. Its colour is sometimes velvet black, sometimes brownish black. It occurs both massive and crystallized. The form of the crystals is a rectangular four-sided prism, terminated by a flat four-sided pyramid, the sides of which are set upon the lateral sides of the prism at angles of 104°. Sometimes the edges of the prism are truncated. The sides of the first variety are longitudinally streaked. Fracture uneven. Lustre, resinous. Cleavage threefold, two of them parallel to the sides of the prism, the third parallel to the shorter diagonal of the rhombs. Opaque. Semihard. Scratches glass, but not felspar. Specific gravity from 3·82 to 4·06. When exposed to the air its surface acquires a brownish or ochre yellow colour. Before the blow-pipe it melts into a black glass, attracted by the magnet. Soluble in muriatic acid.

It forms beds in a rock which appears intermediate between actinolite and hornblende.

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* Gehlen's *Jour.* Second Series, iii. 86.

Sp. 8. *Clay Iron-Stone* *.

This extensive species occurs both in the primitive, transition and floetz formations; and though it contains less iron than the species already described, it is, in this country at least, preferred to them, because the method of extracting pure iron from it is easier, or rather because it is better understood. It is divided into seven subspecies.

Subspecies 1. *Reddle—Red Chalk.* This mineral, which occurs chiefly in the newer clay-slate, is principally used for drawing. Found massive. Colour light brownish red. Principal fracture slaty. Cross fracture fine earthy. Lustre of the principal fracture 1; of the cross fracture 0. Fragments usually splintery. Streak lighter, and more shining than the fracture. Soils strongly. Very soft. Sectile. Frangibility 4. Adheres to the tongue. Feels meagre. Specific gravity 3·931 to 3·1391 †.

Subspecies 2. *Columnar Clay Iron-Stone.* A rare mineral, and seemingly pseudo-volcanic, in some cases at least. Found in Arran, and in different parts of Germany. Colour brownish red. Massive. Internal lustre 0. Fracture fine earthy. Almost always in columnar distinct concretions, which have a rough dull surface. Streak blood red. Soft. Brittle. Frangibility 6. Adheres a little to the tongue.

Subspecies 3. *Lenticular Clay Iron-Stone—Acinose Iron-Stone.* Occurs in transition and floetz mountains. Colour brownish red, passing into steel grey, and into

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* Kirwan, ii. 173.—Brochant, ii. 271.—Jameson, ii. 317.

† Blumenbach and Brisson.

reddish, yellowish, and blackish brown. Massive. Internal lustre 1, 2, semimetallic. Fracture apparently earthy, and sometimes slaty. Fragments indeterminate, blunt-edged. In granular and lenticular distinct concretions. Red variety yields a light red streak, the yellowish a yellowish brown, and the black a greyish black streak. Soft. Sectile. Frangibility 5.

Subspecies 4. *Jaspery Clay Iron-Stone.* Found between Vienna and Hungary, in a large bed in floetz mountains. Colour brownish red. Massive. Internal lustre 1. Fracture flat conchoidal, sometimes passing into even. Fragments rhomboidal, cubical, trapezoidal. Streak light. Soft. Brittle. Frangibility 4. Heavy.

Subspecies 5. *Common Clay Iron-Stone.* Occurs in beds in floetz mountains. Found abundantly both in Scotland and England. Colour light yellowish grey, inclining to ash grey; it passes into bluish grey, and, into yellowish, reddish, and clove brown, and brownish red. The light varieties change their colour on exposure; they become yellowish, then brown, and at last black. Massive and in various extraneous shapes, especially of shells. Internal lustre 0. Fracture usually earthy, sometimes flat conchoidal and even. Fragments indeterminate, blunt-edged. Soft. Rather brittle. Frangibility 4. Adheres a little to the tongue. Feels meagre. Specific gravity from 2·936 to 3·471.

Subspecies 6. *Kidneyform Clay Iron-Stone—Oetites* or *Eagle Stone.* Occurs imbedded in iron-shot clay in the newest floetz rocks. Common in Scotland and other countries. Colour yellowish brown, varying in intensity in the same specimen; externally being darker, and internally lighter. Sometimes it includes an ochre yellow kernel. In roundish masses, from the size of a walnut to that of a man's head. Fracture near the surface even, near the centre earthy. Lustre of external layers 1, semimetallic; of the centre 0. Fragments indeterminate. In concentric lamellar distinct concretions, inclosing a nodule often loose. Surface of concretions rough and glimmering. External layers soft, internal very soft. Brittle. Frangibility 4. Adheres to the tongue. Specific gravity 2·574.

Subspecies 7. *Pisiform Iron-Stone.* Supposed to occur in the second floetz lime-stone formation, and in clay beds. Found in Scotland, and in various parts of Germany, &c. Colour within yellowish brown; without reddish, yellowish, and liver brown, and sometimes yellowish grey. In small, round, and spherical grains. Internally it passes from dull to glistening; the centre of the grain being dull, and the lustre increasing as we approach the surface. Lustre resinous. Fracture towards the centre fine earthy, near the surface even. In thin concentric lamellar distinct concretions, having a smooth glistening surface. Streak yellowish brown. Soft. Not very brittle. Frangibility 4. Specific gravity 5·207.

Sp. 9. *Bog Iron Ore* *.

This species belongs to the newest formation, and is supposed to be daily deposited from water in morassy grounds. It is divided into three subspecies.

Subspecies 1. *Morass Ore.* Colour yellowish brown. Sometimes friable; sometimes nearly cohering. The friable composed of dull dusty particles; the coherent

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* Kirwan, ii. 179.—Brochant, ii. 282.—Jameson, ii. 334.

massive, corroded, and in grains. Lustre 0. Fracture earthy. Soils pretty strongly. Feels meagre. Light.

Subspecies 2. *Swamp Ore.* Colour dark yellowish brown. Corroded, vesicular, and amorphous. Internal lustre 0, 1, 2. Fracture earthy, passing into finegrained uneven. Streak yellowish brown. Very soft. Sectile. Frangibility 4. Specific gravity 2·944 [*].

Subspecies 3. *Meadow Ore.* Colour, when fresh broken, blackish brown. Massive, in grains, perforated, &c. Internal lustre 3, 2, resinous. Fracture imperfect small conchoidal; sometimes passes into small-grained uneven. Fragments indeterminate, bluntedged. Streak light yellowish grey. Soft. Rather brittle. Frangibility 5. Heavy.

Few of the numerous species belonging to this genus have been subjected to chemical analysis. The following Table exhibits a view of the constituents of those which have been ascertained.

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[*] Kirwan.

Oxides.

	Iron Froth.	Iron Sand.	Compact Red Iron Stone.	Sparry Iron-Stone.												Yenite.	
	*	†	‡	§	§	‖	‖	‖	¶	¶	**	**	††	††	‡‡	§§
Oxide of iron	94·5	85·3	65·4	38	22	52·75	42·38	42·38	49	50·5	55	73·75	57·5	58	55	57·5
Arsenic		1														
Ox. of mangan.			2·7	24	28				1·5	10	10	10·5	3·5	4·25	3	
Ox. of titanium		9·5														
Silica	4·25		10·7					0·8		2					28	30
Alumina	1·25	1·5	9·3												0·6	
Lime				38	50				0·3	0·5		2·75	1·25	0·5	12	12·5
Magnesia						5	14	13·6	12·5	2				0·75		
Carbonic acid Water						42·25	43·62	43·22	37·5	34·5	35	13	36	35		
Loss		2·7	1·9							0·5			1·75	1·5	1·4	
	100	100	100	100	100	100	100	100	100·8	100	100	100	100	100	100	100

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* Henry, Nicholson's 4to *Journal*, iii. 456. Bucholz found it pure red oxide mixed with a little quartz sand. Gehlen's *Jour.* Second Series, iii. 106.

† By my analysis. *Trans. Edin.* vi. 254. The specimen was from the river Don, Aberdeenshire. It probably contained a little *iserine*. Hence the oxide of titanium, and a little arsenical pyrites. Hence the arsenic.

‡ Lampadius, *Handbuch*, p. 269.

§ Bergman, *Opusc.* ii. 228. The lime was in the state of carbonate, as was the manganese.

‖ Drappier, Gehlen's *Jour.* Second Series, ii. 471.

¶ Collet, Descotils, Ibid. p. 476.

** Bucholz, Ibid. iii. 114.

†† Klaproth, *Beitrage*, iv. 107.

‡‡ Descotils, Gehlen's *Jour.* Second Series, iii. 87.

§§ Vauquelin, Ibid.

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	Lenticular Clay IronStone	Common Clay Iron-Stone.								Pisiform Iron-Stone.			Meadow Ore.
	*	*	*	†	†	†	†	†	†	‡	§	‖	¶
Oxide of iron	64	35	39	33·5	42·5	39·1	33·9	20·1	20·2	48	60	53	66
Ox. of mangan.				1·5	3	1·1	1·1	1	0·5			1	1·5
Silica	7·5	11	5	14·3	13·8	11·9	23·9	19·9	29·9	15	12	23	
Alumina	23	39	40	22·6	13·6	15·8	13	30·2	25·4	31	13	6·5	
Magnesia		2	6										
Phosphoric acid													8
Carbonic acid				28·	27·1	32·1	28·1	28·8	24·0				
Water	5	10	9							6	15	14·5	23
Sulphur		3	1										
Loss	0·5											2	1·5
	100	100	100	100	100	100	100	100	100	100	100	100	100

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* Lampadius. Jameson, ii. 323 and 328. † Richter, Crell's *Annals*, 1796, i. 550 ‡ Vauquelin, *Jour. de Min.* No. xii. p. 14. § Molinghof. Jameson, ii. 333. ‖ Klaproth, *Beitrage*, iv. 128. ¶ Ibid. 123.

Salts.

GENUS IV. SALTS.

Sp. 1. *Carbonate of Iron*[*].

THIS mineral was found in Bareuth, and sent by Mr Haberle to Bucholz, who subjected it to a chemical analysis, and ascertained its composition. Colour brownish yellow, falling into green. Sometimes in small grains; sometimes in rhomboidal crystals. Lustre 2. Transparency 2. Hard. Powder brownish yellow. Specific gravity 3·333. When heated to redness it becomes strongly magnetic, attracting iron. It is probably a variety of sparry iron stone.

Sp. 2. *Phosphate of Iron*[†].

This mineral has been found in Brazil, and in the Isle of France. Its composition was first detected by Vauquelin. Specimens brought by Mr Roch from the Isle of France were subjected to chemical analysis by Cadet and Laugier.

It is said to be found imbedded in a species of clay, in round pieces. Fracture radiated. Composed of capillary crystals diverging from a centre. Crystals apparently four-sided prisms. Transparency of the individual crystals 2. They are nearly colourless, but a blue powder coats them, which gives a blue appearance to the whole mineral. The constituents both

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[*] Bucholz, Gehlen's *Jour.* i. 231.

[†] Cadet, *Jour. de Phys.* lvii. 259.—Fourcroy, *Ann. de Chim.* l. 200.

of the crystals and powder the same. Specific gravity 2·539, according to Cadet; 2·6, according to Laugier.

Sp. 3. *Blue Iron-Earth* *—*Native Prussian Blue.*

This mineral is considered at present as a phosphate of iron, in consequence of the analysis of Klaproth. It occurs in nests among the strata of clay, bog iron ore, or in mosses. It is massive, composed of earthy particles without lustre, and friable. At first its colour is greyish white, but when exposed to the air it becomes indigo or smalt blue. Soils slightly. Feels harsh. Moderately heavy. Before the blow-pipe becomes reddish brown, and melts into a black brilliant globule, which tinges borax deep yellow. Dissolves readily in acids.

Sp. 4. *Phosphate of Iron and Manganese* †—*Pitchy Iron Ore.*

This mineral was discovered by Alluau near Limoges, and sent to Vauquelin as an ore of tin. It is found massive. Colour raven black. Surface earthy, and without lustre: internal lustre 3, 4, resinous. Fracture flat and pretty perfect foliated. Fragments indeterminate, pretty sharp-edged. Transparency 1. When held between the eye and the light, appears blackish green on the edges. Hardness 7. Brittle. Frangibility 2. Specific gravity 3·956. Before the blow-pipe it melts into a black enamel.

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* Kirwan, ii. 185.—Brochant, ii. 288.—Hauy, vi. 119.—Jameson, ii. 340.

† *Jour. de Min.* No. lxiv. 295.—*Ann. de Chim.* xli. 242.—Brochant, ii. 533.—Jameson, ii. 569 and 612.

Sp. 5. *Arseniate of Iron.—Cube Ore.*

This ore was first mentioned by Klaproth, but mistaken by him for arseniate of copper containing iron *: it has been found in Carrarach and in Muttrell mines in Cornwal. For the description of it we are indebted to Bournon, and for its analysis to Chenevix.

This ore is crystallized in cubes, which are sometimes a little flattened, and in some cases the angles are truncated, and small equilateral triangular faces substituted for them. Sometimes the alternate angles only are truncated. Colour olive green. Internal lustre 2, between pearly and adamantine. Fracture imperfect foliated. In granular distinct concretions. Transparency about 2. Streak straw yellow. Brittle. Soft. Specific gravity 3·00. Sometimes in the state of a powder of a reddish yellow colour †.

Sp. 6. *Arseniate of Iron-and-Copper.*

This ore has been found in Carrarach and Muttrell mines in Cornwal. It was discovered likewise in Spain by Proust ‡, and in Siberia by Pallas §. It was first mentioned by Klaproth, who considered it as an arseniate of copper ‖; but the experiments of Mr Chenevix have proved it to be a triple salt, composed of the arsenic acid combined with the oxides of iron and cop-

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* Klaproth's *Observations on the Minerals of Cornwal*, p. 29. English Translation.

† *Phil. Trans.* 1801, p. 190.

‡ *Ann. de Chim.* i. 195.

§ *Phil. Trans.* 1801, p. 219.

‖ Klaproth's *Observations on the Minerals of Cornwal*, p. 29. English Translation.

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per. This ore crystallizes in a four-sided rhomboidal prism, having two of its edges very obtuse, and two very acute. The prism is terminated by a pretty acute four-sided pyramid. Very often the obtuse edges, and sometimes all the edges of the prism, are truncated. Colour bluish white. Transparency of the crystals 4. Hardness 7. Specific gravity 3·400 *.

Sp. 7. *Green-Iron-Earth* †.

This rare mineral has been found in veins at Schneeberg and Braunsdorf in Germany. It is divided into two subspecies.

Subspecies 1. *Friable.* Colour siskin green. Massive and disseminated. In dull dusty particles. Fracture fine earthy. Fragments indeterminate. More or less cohering. Soft. Not very brittle. Feels fine, but meagre. Frangibility 4. Moderately heavy.

Subspecies 2. *Coherent.* Colour as the preceding, only darker. Massive and corroded. Internal lustre 0. Fracture fine earthy; passing into even and into splintery. Soft. Not particulary brittle. Inclining to heavy. Becomes red, and then brown, before the blow-pipe, but does not melt.

Sp. 8. *Sulphate.*

This salt is found sometimes along with iron pyrites. Its properties have been described in a former part of this Work.

The mineral usually called native vitriol is a mixture of the sulphates of iron, copper, and zinc.

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* Bournon, *Phil. Trans.* 1801, p. 191.

† Jameson, ii. 342.

Salts.

Sp. 9. *Tungstate.* See Order XXI. Genus I.
Sp. 10. *Chromate.* See Order XVIII. Genus III.

The following Table exhibits the constituents of the preceding species, as far as they have been ascertained by chemical analysis :

Constituents.

	Carbonate of Iron	Arseniate of Iron.		Blue Iron Earth.	Phosphate of iron and Manganese.	Arseniate of Iron.		Arseniate of Iron and Copper.
	*	†	‡	§	‖	**	††	‡‡
Oxide of iron	59·5	41·25	42·1	47·5	31	48	45·5	27·5
Ox. of mangan.					42			
Ox. of copper							9	22·5
Carbonic acid	36							
Phosphor. acid		19·25	26·9	32	27			
Arsenic acid						18	31	33·5
Silica		1·25	3				4	3
Alumina		5	5·8					
Lime	2·5		9·1			2		
Water	2	31·25	13·1	20		32	10	12
Loss		2		0·5				1·5
	100	100	100	100	100	100	100	100

ORDER VIII. ORES OF NICKEL.

HITHERTO the ores of nickel have been found only in a small quantity, and always in veins. They occur both in primitive and floetz mountains, and are usually accompanied by cobalt. Hitherto only two species of nickel ores have been recognised by mineralogists.

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* Bucholz, Gehlen's *Jour.* i. 248.
† Laugier, *Ann. de Chim.* l. 214.
‡ Oadet, *Jour. de Phys.* lviii. 261.
§ Klaproth, *Beitrage*, iv. 120.
‖ Vauquelin, *Ann. de Chim.* xli. 242.
** Vauquelin.
†† Chenevix, *Phil. Trans.* 1801, p. 221.
‡‡ Chenevix, Ibid. p. 220.

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GENUS I. ALLOYS.

Sp. 1. *Copper Nickel*—Kupfer Nickel.*

THIS, which is the most common ore of nickel, occurs either massive or disseminated, but never crystallized.

Colour copper red. Internal lustre 2 to 3, metallic. Fracture imperfect conchoidal; sometimes passing into coarse and small grained uneven. Fragments indeterminate, sharp-edged. Hardness 8. Brittle. Frangibility 2. Specific gravity 6·6086 to 6·6481†. Before the blow-pipe exhales an arsenical smoke, and melts into a bead; which darkens by exposure to the air. This ore, when pure, is merely an alloy of nickel and arsenic; but it frequently contains cobalt and iron, and always a portion of pyrites.

GENUS II. OXIDES.

Sp. 1. *Nickel Ochre*‡.

This mineral occurs almost always as a thin coating. Seldom massive.

Colour apple green. Composed of dull dusty particles, which scarcely soil. Loose. Feels meagre. Specific gravity inconsiderable. Stains. Slowly dissolves in acids: solution green. Before the blow-pipe does not

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* Kirwan, ii. 286.—Brochant, ii. 408.—Hauy, iii. 503.—Jameson, ii. 448.

† Brisson.

‡ Kirwan, ii. 284.—Brochant, ii. 411.—Hauy, iii. 516.—Jameson, ii. 451.

Ores of Tin.

melt; but gives a hyacinth red tinge to borax, and is reduced. Insoluble in nitric acid.

Constituents.

According to the analysis of Lampadius, it is composed of

Oxide of nickel	67·0
Oxide of iron	23·2
Water	1·5
Loss	8·3
	100·0[*]

ORDER IX. ORES OF TIN.

TIN ores are by no means numerous; but where they do occur they are usually abundant. In Europe only three tin districts are known: the first is in Germany, between Saxony and Bohemia; the second in Spain, in that part of Gallicia which borders on Portugal; and the third in Cornwal. In Asia, it abounds in Siam and the island of Barka: it is said likewise to have been discovered in Chili. The ores are confined to the primitive mountains, or they occur in alluvial land, and have obviously been washed from primitive mountains. Few metals exhibit a smaller variety of states; since it has hitherto been found only in three, as may be seen from the following Table:

I. SULPHURETS
    1. Sulphuret of tin-and-copper

II. OXIDES
    1. Tin-stone
    2. Wood-tin

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[*] *Handbuch*, p. 297.

GENUS I. SULPHURETS.

Sp. 1. *Tin Pyrites* *.

Hitherto this ore has only been found in Cornwal. There is a vein of it in that country, in the parish of St Agnes, nine feet wide and twenty yards beneath the surface †.

Colour between steel grey and brass yellow. Massive and disseminated. Internal lustre 2, 3, 4, metallic. Fracture usually uneven; sometimes conchoidal and imperfect foliated. Fragments blunt-edged. Frangibility 4. Hardness 5 to 6. Brittle. Specific gravity 4·35 ‡. Before the blow-pipe it melts easily, with a sulphureous smell, into a black bead, and deposites a bluish oxide on the charcoal. The composition of this ore, as Klaproth informs us, was first discovered by Mr Raspe. According to Klaproth's analysis, it is composed of..............34 tin

Constituents.

36 copper
25 sulphur
3 iron
2 earth
———
100 §

GENUS II. OXIDES.

Sp. 1. *Tin-Stone* ||.

This ore, which may be considered as almost the on-

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* Kirwan, ii. 200.—Brochant, ii. 332.—Hauy, iv. 154.—Jameson, ii. 382.—*Ann. de Chim.* liii. 266.

† Klaproth's *Cornwal*, p. 21. ‡ Klaproth. § Ibid. 58.

|| Kirwan, ii. 197.—Brochant, ii. 354.—Hauy, iv. 137.—Jameson, ii. 384.

ly ore of tin, occurs in masses, in rounded pieces, and crystallized. These crystals are very irregular. Hauy supposes that there primitive form is a cube [*]; but Romé de Lisle, with more probability, makes it an octahedron [†]; and in this opinion Mr Day agrees with him [‡]. The octahedron is composed of two four-sided pyramids applied base to base. The sides of the pyramids are isosceles triangles; the angle at the vertex of which is 70°, and each of the other angles 55°. The sides of the two pyramids are inclined to each other at an angle of 90° [§]. This primitive form, however, never occurs; but crystals of tin-stone are sometimes found, in which the two pyramids are separated by a prism. For a complete description of the varieties of the crystals of tin-stone, the reader may consult Romé de Lisle, and Mr Day [‖].

Colour blackish brown; sometimes passing into velvet black and reddish brown, yellowish grey, green, yellowish and greenish white. Streak greyish white. Internal lustre 3, 2, between resinous and adamantine. Fracture uneven inclining to imperfect conchoidal. Very seldom foliated. Fragments blunt-edged; often in granular distinct concretions. Transparency from 3 to 0. Hardness 10. Frangibility 4. Brittle. Specific gravity 6·9 to 6·97. Before the blow-pipe it decrepitates, and on charcoal is partly reduced. Tinges borax white.

Sp. 2. *Wood-Tin* [¶].

This mineral has hitherto been found only in Corn-

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[*] *Jour. de Min.* xxxii. 576.

[†] *Crystallog.* iii. 413.

[‡] *Phil. Mag.* iv. 152.

[§] Romé de Lisle, Ibid.

[‖] Ibid.

[¶] Kirwan, ii. 198.—Brochant, ii. 340.—Hauy, iv. 147.—Jameson, ii. 389.

wal, and in Mexico. It occurs always in fragments, which are generally rounded. Colour hair brown; passing into wood brown, yellowish grey, reddish brown. Streak yellowish brown. Internal lustre 3, 2, resinous. Opaque. Fracture fibrous. Fragments wedge-shaped and splintery. In granular distinct concretions. Specific gravity 6·450 [*] to 6·738 [†]. Hardness 9. Before the blow-pipe becomes brownish red; decrepitates when red hot, but is not reduced.

The following Table exhibits the constituents of the preceding species, according to the result of the most accurate analyses hitherto made:

Constituents.

	Tin-Stone.				Wood-Tin.
	‡	‡	§	‖	¶
Oxide of tin	99	99·5	84	95	91
Oxide of iron	0·25	0·5	9	5	9
Silica	0·75		7		
	100	100	100	100	100

ORDER X. ORES OF LEAD.

ORES of lead occur in great abundance in almost every part of the world. They are generally in veins,

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[*] Klaproth.

[†] Humboldt.

[‡] Klaproth, *Beitrage*, ii. 256.

[§] Lampadius, *Handbuch*, p. 280.

[‖] Collet, Descotils, *Ann. de Chim.* liii. 268.

[¶] Vauquelin, Gehlen's *Jour.* v. 251.

Sulphurets.

but sometimes in beds; and they occur both in the primitive, transition, and floetz formations.

The following Table exhibits a view of the different states in which this mineral has hitherto been observed:

Table of the Species.

- I. SULPHURETS
  - 1. Galena
  - 2. Blue lead ore
  - 3. Antimonial sulphuret
- II. OXIDES
  - 1. Earthy ore of lead
  - 2. Native minium
- III. SALTS
  - 1. Carbonate
  - 2. Black lead ore
  - 3. Muriocarbonate
  - 4. Phosphate
  - 5. Chromate
  - 6. Sulphate
  - 7. Molybdate
  - 8. Arseniate
  - 9. Arseniophosphate

Of these the first species is by far the most common. From it indeed almost the whole of the lead of commerce is extracted.

GENUS I. SULPHURETS.

Sp. 1. *Galena* *.

This ore is divided into two subspecies.

Subspecies 1. *Common Galena.* This ore, which is very common, is found both in masses and crystallized. The primitive form of its crystals is a cube. The most common varieties are the cube, sometimes with its angles wanting, and the octahedron, composed of two

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* Kirwan, ii. 216.—Brochant, ii. 295.—Hauy, iii. 456.—Jameson, ii. 346.

four-sided pyramids applied base to base. The summits of these pyramids are sometimes cuneiform, and sometimes their solid angles are wanting *. It occurs also in four and six-sided prisms terminated by four-sided pyramids, and in three-sided tables.

Colour lead grey. Streak similar, but brighter. External lustre 4 to 1; internal 4 to 2, metallic. Fracture foliated; cleavage threefold and rectangular. Fragments cubic. The massive varieties are in granular distinct concretions. Soft. Sectile. Frangibility 6. Specific gravity 7·22 to 7·786 †. Before the blow-pipe decrepitates, and melts with a sulphureous smell; part sinks into the charcoal. It generally contains some silver.

Subspecies 2. *Compact Galena.* Found massive; sometimes in specular plates. Colour lead grey. Internal lustre 1, metallic. Fracture even. Never in distinct concretions. Softer than common galena. Streak brighter. Fragments indeterminate. In other respects agrees with the preceding.

Sp. 2. *Blue Lead Ore* ‡.

This ore has hitherto been observed only at Zschopau in Saxony. Occurs massive, and crystallized in small six-sided prisms. Colour between indigo blue and lead grey. Internal lustre 1, metallic. Streak brighter. Fracture even. Fragments indeterminate. Soft. Sectile. Frangibility 4. Specific gravity 5·461 §. Before the blow-pipe melts with a low blue flame and

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* Rome de Lisle, iii. 364.—Hauy, iii. 458.

† Watson.

‡ Kirwan, ii. 220.—Brochant, ii. 303.—Jameson, ii. 356.

§ Gellert.

a sulphureous smell, and is easily reduced. It has not been analysed. Its crystals resemble those of phosphate of lead; but its component parts seem to be the same as those of galena.

Sp. 3. *Antimonial Sulphuret* *—*Bournonite.*

This rare ore was first obtained from Cornwal, and was neglected by mineralogists, till accurately described and analysed by Bournon and Hatchett in 1804. Various specimens have been since analysed by Klaproth.

Colour dark lead grey, inclining to black. Massive, and crystallized in four-sided rectangular prisms, variously truncated. All the varieties have been described and figured by Bournon with his usual precision. Crystals large; surface splendent. Internal lustre 2, resinous. Fracture coarse grained uneven. Scratches calcareous spar, but not fluor spar. Sectile. Frangibility 4. Leaves a black trace upon paper, but not so readily as lead or sulphuret of antimony. Specific gravity 5·765. When thrown in powder on a hot iron, emits a phosphorescent light of a bluish white colour, but without any smell. When suddenly heated by the blow-pipe, it crackles and splits; but when gradually heated it melts, and on cooling assumes a metallic grey colour.

The following Table exhibits a view of the constituents of the preceding species, according to the most recent analyses:

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* Bournon and Hatchett, *Phil. Trans.* 1804.—Klaproth, Gehlen's *Jour.* v. 31.—Jameson, ii. 579.

Book III. Chap. II. Constituents.

	Galena.							Antimonial Sulphuret.			
	*	*	*	*	*	†	‡	§	‖	¶	**
Lead	54	69	69	68	64	83·00	85·13	42·62	42·5	34·5	39
Antimony								24·23	19·75	16	28·5
Copper								12·8	11·75	16·25	13·5
Silver						0·08	0·5			2·25	
Iron								1·2	5	13·75	1
Sulphur	8	16	18	16	18	16·41	13·02	17	18	13·5	16
Limeandsilica	38	15	13	16	18					2·5	
Loss						0·51	1·35	2·15	3	1·25	2
	100	100	100	100	100	100	100	100	100	100	100

* Vauquelin, *Jour. de Min.* No. ix. p. 69.

† Westrumb, Jameson's *Min.* ii. 35.

‡ By my analysis.

§ Hatchett, *Phil. Trans.* 1804.

‖ Klaproth, Gehlen's *Jour.* v. 34. The specimen from Alten Segen in Clausthal.

¶ From St Andreasberg, Klaproth, *Beitrage*, iv. 86.

** From Nanslo in Cornwal, Ibid. p. 87.

Oxides.

Genus II. Oxides.

It is doubtful how far any of the known ores of lead can be referred to this genus. *Earthy lead ore*, however, seems, sometimes at least, to be a mixture of the oxide of lead with earthy matter.

Sp. 1. *Earthy Lead Ore*[*].

Of this ore there are two subspecies, the *coherent* and *friable*.

Subspecies 1. *Coherent.* Most frequent colour yellowish grey; passes into straw yellow, greenish grey, sisken and apple green, and into yellowish brown. Massive. Internal lustre 1, 2, resinous. Fracture fine-grained uneven; passing into splintery and earthy. Opaque. Streak brown. Soft. Inclining to sectile. Frangibility 4. Heavy.

Subspecies 2. *Friable.* Colour yellowish grey and straw yellow. Friable; sometimes massive, and as a coating. Composed of dull dusty particles. Meagre and rough. Heavy.

Sp. 2. *Native Minium*[†].

This ore has been lately discovered by Mr Smithson in Germany, disseminated in small quantity in a compact carbonate of zinc. In general it was in a pulverulent state, but in places showed to a lens a flaky and crystalline texture. Its colour is the same as that of factitious minium, a vivid red mixed with yellow. It

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[*] Kirwan, ii. 205.—Brochant, ii. 327.—Jameson, ii. 378.

[†] Smithson, *Phil. Trans.* 1806.

possesses the chemical characters of red oxide of lead, and must of course be considered as the same substance.

According to Mr Smithson, it is produced by the decay of a galena, which he suspects to be itself a secondary production, from the metallization of white carbonate of lead by sulphureted hydrogen gas.

GENUS III. SALTS.

Sp. 1. Carbonate of Lead—White Lead Ore.*

This is the most generally diffused lead ore after galena, though it seldom occurs in any considerable quantity together. Colour snow, greyish, and yellowish white; yellowish grey; cream yellow; clove brown. Massive and disseminated, but most commonly crystallized. Primitive form the rectangular octahedron; But it occurs most frequently crystallized in six-sided prisms, terminated by six or four-sided summits; in four-sided prisms; and four and six-sided tables, often variously bevelled. Crystals usually small. External lustre 4 to 2; internal from 4 to 2, adamantine. Fracture commonly small conchoidal; sometimes passes into fine grained uneven. Fragments indeterminate. Transparency 2 to 4. Refracts doubly very strongly. Soft. Brittle. Frangibility 4. Specific gravity 7·2357†. Before the blow-pipe decrepitates; becomes red, then yellow, and at last is reduced to a globule of lead.

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* Kirwan, ii. 203.—Klaproth, iii. 167.—Hauy, iii. 475.—Brochant, ii. 309.—Jameson, ii. 362.

† Bournon, Nicholson's *Jour.* iv. 220.

Sp. 2. *Black Lead Ore*[*].

This ore often accompanies white lead ore and galena. Colour greyish black. Massive, and crystallized in six-sided prisms. External lustre 4, 3; internal 3, 2, adamantine. Fracture small grained uneven. Transparency 1. Streak greyish white. Rather brittle. Frangibility 4. Heavy.

Sp. 3. *Murio-Carbonate of Lead.*

For the first description of this ore which has hitherto been observed in Derbyshire only, we are indebted to the Count de Bournon. The primitive form of its crystals is the cube, often lengthened, and the edges or the angles not unfrequently truncated, and replaced by small planes. Colour usually a light straw yellow; sometimes a clear transparent white, with a lustre far surpassing common carbonate of lead. Internal lustre 4, adamantine. Principal fracture glassy, foliated; cross fracture conchoidal. Transparency 3. Streak snow white and dull. Sectile. Scratched by carbonate of lead. Specific gravity 6·0651 †.

Sp. 4. *Phosphate of Lead*‡.

Werner makes two species of this ore, distinguished chiefly by their colour; namely, the *brown* and *green* lead ore. We may consider them as subspecies. The primitive form of its crystals is a dodecahedron, con-

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[*] Kirwan, ii. 221.—Brochant, ii. 307.—Jameson, ii. 360.

† Bournon, Nicholson's *Jour.* iv. 220.

‡ Kirwan, ii. 207.—Klaproth, iii. 146.—Hauy, iii. 490.—Brochant, ii. 314.—Jameson, ii. 367.

sisting of two six-sided pyramids, the sides of which are isosceles triangles *. The crystals are usually six-sided prisms, sometimes terminated by six-sided summits. The summits are sometimes truncated, as are also the edges of the prism.

Subspecies 1. *Brown Phosphate—Brown Lead Ore.* Colour hair brown of different degrees of intensity. Massive, and crystallized in six-sided prisms. Internal lustre 2, resinous. Fracture small and fine grained uneven. Fragments indeterminate. Crystallized varieties show a tendency to thin columnar distinct concretions. Transparency 2. Soft. Not particularly brittle. Frangibility 4. Specific gravity from 6·600 to 6·909 †.

Subspecies 2. *Green Phosphate—Green Lead Ore.* Colour grass green, which passes to sulphur yellow and to greenish white. Seldom massive; usually crystallized in six-sided prisms, often variously truncated. Crystals small. Externally smooth and shining. Internal lustre 2, resinous. In other respects it agrees with the preceding.

Before the blow-pipe this ore melts without being reduced, and on cooling assumes a polygonal form. The yellow varieties become green when heated.

Sp. 5. *Chromate of Lead* ‡—*Red Lead Ore of Siberia.*

This mineral, which has now become scarce, is found in the gold mines of Beresof near Ekaterinbourg in

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* Rome de Lisle, iii. 391.—See also Hauy's remarks on the same subject, in *Jour. de Min.* No. xxxi. 506, and *Min.* iii. 491.

† Klaproth and Hauy.

‡ Kirwan, ii. 214.—Brochant, ii. 318.—Hauy, iii. 467.—Jameson, ii. 370.

Siberia, crystallized in four-sided prisms, sometimes terminated by four-sided pyramids, sometimes not. It has been observed also at Annaberg in Austria, and at Trapettes in Savoy.

Colour hyacinth red. Streak and powder lemon yellow. Lustre 4, between adamantine and resinous. Fracture foliated. Fragments indeterminate, blunt-edged. Transparency 2 to 4. Hardness 5 to 4. Specific gravity 6·0269 * to 5·75 †. Does not effervesce with acids. Before the blow-pipe decrepitates; some lead is reduced, and the mineral is converted to a black slag, which tinges borax green.

A brown ore of lead from Zimapan in Mexico, brought to Europe by Humboldt, was found by Descotils to be a compound of chromic acid and oxide of lead; but the proportion of acid was considerably smaller than in the red lead ore. This ore seems to constitute a species apart, but no description of it has been published ‡.

Sp. 6. *Sulphate of Lead* §.

This ore, which is found in Anglesey, in the Lead-hills in Scotland, and in Andalusia, is generally crystallized. The primitive form of its crystals is a rectangular octahedron, with obtuse pyramids. The pyramids are often variously truncated. Colour yellowish grey and yellowish white; sometimes passes into

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* Brisson. † Bindheim.

‡ *Ann. de Chim.* lviii. 268.

§ Kirwan, *Min.* ii. 211.—Klaproth, iii. 162.—Hauy, iii. 513.—Brochant, ii. 325.—Jameson, ii. 376.

smoke and ash grey. External lustre 3; internal 4, adamantine. Fracture compact. Transparency 3. Hardness 6. Brittle. Specific gravity 6·3. Immediately reduced before the blow-pipe.

Sp. 7. *Molybdate of Lead*[*].

This ore, which is found in Carinthia, was first mentioned in 1781 by Mr. Jacquin[†]. It occurs sometimes massive, but usually crystallized in cubic, or rhomboidal, or octahedral plates. The primitive form of its crystals is an octahedron with isosceles triangular faces; the incidence of a face of one pyramid on that of another 76° 40′[‡].

Its colour is wax yellow. External lustre 3; internal 2, resinous. Fracture small-grained uneven, passes into imperfect small conchoidal. Fragments sharp-edged. Transparency 2. Between brittle and sectile. Frangibility 4. Hardness 5 to 6. Specific gravity 5·486[§]; when purified from its gangue by nitric acid, 5·706[‖]. Soluble in fixed alkalies and in nitric acid. Communicates a blue colour to hot sulphuric acid. Soluble in muriatic acid, and decomposed by it. Before the blow-pipe decrepitates, melts into a yellowish grey mass, and globules of lead are reduced[¶].

Sp. 8. *Arseniate of Lead*[**].

This ore, which has been hitherto found only at Jo-

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[*] Kirwan. ii. 212.—Klaproth, *Ann. de Chim.* viii. 103.—Hatchett, *Phil. Trans.* 1796, p. 285.—Hauy, iii. 498.—Brochant, ii. 322.—Jameson, ii. 373.

[†] In his *Miscellanea Austriaca*, vol. ii. p. 139.

[‡] Hauy. [§] Macquart. [‖] Hatchett. [¶] Macquart.

[**] Karsten, Gehlen's *Jour.* iii. 60.

hann-Georgenstadt, was at first confounded with the preceding, till the analysis of Rose showed that it contained no molybdic acid. Colour wax yellow, passing into asparagus green. Crystallized in double six-sided pyramids. External lustre 4, 3, adamantine; internal 3, resinous. Fracture splintery. Transparency 2. Soft. Sectile. Specific gravity 7·2612.

Karsten in his catalogue, published in 1790, describes an ore from Siberia, which likewise contains arsenic acid and lead; but iron is also present in it in considerable quantity. We are not yet in possession of a good description of the arseniate of lead found by Proust in Spain.

The following Tables exhibit a view of the constituents of the preceding species, according to the most exact analyses hitherto made.

	Carbonate.			Black Lead Ore.	Murio-Carbonate.		Phosphate.				
	*	*	†	‡	§	¶	‖	‖	‖	‖	**
Oxide of lead	81·2	80·25	82	78·5	85	85·5	78·58	78·4	77·1	80	79
Carbonic acid	16	16	16	18	6	6					
Muriatic acid					8	8 5	1·65	1·7	1·54	1·62	
Phosphoric							19 73	18·37	19	18	18
Oxide of iron	0·3	0·18						0·1	0·1		1
Alumina		0·75									
Lime	0·9	0·5									
Charcoal				1·5							
Water				2							2
Loss	1·6	2·32	2		1	·04	·04	1·43	2·26	0·38	
	100	100	100	100	00	100	100	100	100	100	100

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* Westrumb.

† Klaproth, *Beitrage*, iii. 167.

‡ Lampadius, *Handbuch*, p. 275.

§ Chenevix, Nicholson's *Jour.* iv. 220.

¶ Klaproth, *Beitrage*, iii. 141.

‖ Id. Ibid. iii. 146.

** Fourcroy.

Salts.

	Chromate.		Brown Chromate.	Sulphate.		Molybdate.		Arseniate.
	*	†	‡	§	§	‖	¶	**
Oxide of lead	65·12	64	74·2	71	70·5	64·42	58·4	77·5
Muriatic acid			1·5					1·5
Chromic	34·88	36	16					
Sulphuric				24·8	25·75			
Molybdic						34·25	8	
Arsenic								12·5
Phosphoric								7·5
Oxide of iron			3·5	1			2·1	
Silica							0·28	
Water				2	2·25			
Loss			4·8	1·2	1·50	1·33	1·22	1
	100	100	100	100	100	100	100	100

ORDER XI. ORES OF ZINC.

THOUGH the ores of zinc are very few in number, they are by no means scarce. Blende, the most abundant of them, occurs most frequently in transition rocks, though sometimes also it is found in primitive and floetz rocks, and is almost always accompanied by Galena. Calamine, the only other ore of zinc, seems

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* Vauquelin, *Jour. de Min.* No. 34, p. 760. † Thenard.

‡ Collet, Descotels, *Ann. de Chim.* liii. 271.

§ Klaproth, *Beitrage*, iii. 162. ‖ Id. Ibid. ii. 275.

¶ Hatchet. *Phil. Trans.* lxxxvi. 323.

** Rose, Gehlen's *Jour.* Second Series, i. 222. Rose published an analysis of this ore, and found it arseniate of lead. Laugier repeated the experiments, and found phosphoric acid, and only traces of arsenic acid. (*Ann. de Museum d'Hist. Naturelle*, vi. 163.) The analysis in the table was made by Rose, in consequence of the publication of Laugier's paper, and appears much more accurate than any of the preceding.

to be nearly confined to floetz rocks; and it occurs most frequently in beds in a particular lime-stone *.

The following Table exhibits the different states in which this metal has hitherto occurred:

I. SULPHURETS
- 1. Blende

II. OXIDES
- 1. Silicated oxide

III. SALTS
- 1. Carbonate
- 2. Sulphate

GENUS I. SULPHURETS.

Sp. 1. *Blende* †—*Black Jack.*

THIS ore is common. It occurs both in amorphous masses and crystallized. The primitive form of its crystals is the rhomboidal dodecahedron. The figure of its integrant particles is the tetrahedron ‡.

The principal varieties of its crystals are the tetrahedron; the octahedron; the octahedron with its edges wanting; a 24-sided crystal, 12 of whose faces are trapezoids, and 12 elongated triangles; and, lastly, a 28-sided figure, which is the last variety, augmented by four equilateral triangles §. It is divided into three subspecies, which characterize different formations.

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* Jameson, ii, 414.

† Kirwan, ii. 238.—Berg. ii. 429.—Brochant, ii. 359.—Hauy, iv. 167.—Jameson, ii. 399.

‡ Hauy, *Jour, de Min.* No. xxxiii. 669.

§ See Hauy, Ibid. and Rome de Lisle, iii. 65.

The yellow is the oldest, the black newest, and the brown intermediate.

Subspecies 1. *Yellow Blende.* Colour dark wax yellow and sulphur yellow, passing into asparagus and olive green, and into hyacinth, aurora, and brownish red. All the colours incline somewhat to green. Massive, and crystallized in four-sided prisms, having their edges truncated, and terminated by four-sided pyramids. Surface smooth. Lustre 3, 4, adamantine. Fracture straight foliated, cleavage sixfold; cross fracture conchoidal. Fragments dodecahedral; but seldom perfect. In granular distinct concretions. Transparency 2, sometimes 3. Refraction single. Streak yellowish grey. Semihard. Brittle. Frangibility 4. Specific gravity 4·044 to 4·067. Often phosphoresces when scraped or rubbed *.

Subspecies 2. *Brown Blende.* Of this there are two varieties; the *foliated* and the *fibrous*.

Foliated. Colour reddish and yellowish brown; passes into hyacinth red, and into blackish brown. Massive; and crystallized in tetrahedrons, octahedrons, rhomboidal dodecahedrons, and octahedrons with an intermediate four-sided prism. External lustre 3; internal from 4 to 1, between resinous and adamantine. Fracture foliated; cleavage six-fold. In granular distinct concretions. Transparency 1, 2, 0. Streak yellowish grey and yellowish brown. Semihard. Brittle. Frangibility 4. Specific gravity from 3·77 to 4·048.

Fibrous. Hitherto found only at Geroldseck in the Breisgau. Colour reddish brown. Massive and reni-

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* Bergman.

form. Lustre 2, 1. Fracture fibrous. In granular distinct concretions, intersected by curved lamellar distinct concretions. Opaque. In other respects agrees with the preceding.

Subspecies 3. *Black Blende.* Colour between greyish and velvet black, sometimes brownish black; when held between the eye and the light, appears blood red if transparent. Massive and crystallized. Internal lustre 3, 4, metallic. Fracture foliated; cleavage six-fold, but very indistinct. Fragments indeterminate, pretty sharp-edged. In granular distinct concretions. Mostly opaque. Streak between yellowish grey and light yellowish brown. Semihard. Brittle. Frangibility 4. Specific gravity 3·967 to 4·166.

The following Table exhibits the constituents of this species, according to the analyses hitherto made.

	Yellow Blende.	Brown Blende.		Black Blende.		
	*	*	†	*	*	‡
Zinc	64	44	58·8	45	52	53
Sulphur	20	17	23·5	29	26	26
Iron	5	5	8·4	9	8	12
Lead				6		
Arsenic				1		5
Copper					4	
Silica	1	24	7·0	4	6	
Alumina		5				
Fluoric acid	4					
Water	6	5		6	4	4
Loss			2·3			
	100	100	100	100	100	100

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* Bergman, *Opusc.* ii. 329.

† By my analysis.

‡ Lampadius, *Handbuch*, p. 284.

Oxides.

GENUS II. OXIDES.

Sp. 1. *Calamine.*

THE term *calamine* has been given to all the ores of zinc of a whitish colour, and which are usually employed for making brass. Mineralogists had long suspected that different kinds of minerals were confounded together under this name, and Mr Smithson has lately ascertained that it contains at least three distinct species. The first is a compound of the oxide of zinc and silica, and is distinguished by the property of becoming electric by heat, like the tourmaline. The primitive form of its crystals appears, from the mechanical division of one of them by Mr Hauy, to be an octahedron composed of two four-sided pyramids, whose sides are equilateral triangles *. But the crystals are minute, and their figure not very distinct. They are either four or six sided tables with bevelled edges, six-sided prisms, or three-sided pyramids. Colour usually greyish white. Fracture radiated or foliated. Lustre vitreous. Specific gravity 3·434. Before the blow-pipe decrepitates and shines with a green light. Gelatinizes in acids. A specimen of this mineral, from Regbania in Hungary, yielded Mr Smithson

68·3	oxide of zinc
25·0	silica
4·4	water
97·7	

Another specimen, analysed by Klaproth, contained

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* *Jour. de Min.* No. xxxii. 596.

66 oxide of zinc
33 silica

99

The different analyses of Bergman and Pelletier show, that the proportion of the constituents of this ore vary considerably. The silica sometimes amounts to 52 *per cent.*; sometimes only to 12. This would lead one to suspect that it is not combined with the zinc, but rather mechanically mixed with it.

Genus III. Salts.

Sp. 1. *Carbonate—Calamine.*

Bergman first announced that many calamines are carbonates of zinc. The experiments of that chemist and of Dr Watson* demonstrate, that most of the calamines of this country are in that state; and this has been confirmed by the late experiments of Mr Smithson.

The carbonate of zinc occurs both massive and in crystals; but their form has not yet been ascertained with precision. Colour brownish or yellowish white. In the specimens which I have seen, the texture was compact, the lustre 0, the fragments indeterminate; and the mineral was composed of testaceous pieces. Opaque. Specific gravity, as determined by Smithson, 4·334. Soluble in sulphuric acid with effervescence. Does not gelatinize with acids. Mr Smithson found a specimen from Somersetshire of a mamellated form, composed of

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* *Chemical Essays*, iv. 10.

Salts.

64·8 oxide of zinc
35·2 carbonic acid

100·0

And a specimen in small crystals from Derbyshire contained ....65·2 oxide of zinc
34·8 carbonic acid

100·0

Sp. 2. *Hydrous Carbonate.—Calamine.*

This species is distinguished from the last by its low specific gravity, in which it nearly agrees with silicated oxide of zinc. The specimen examined by Mr Smithson was from Bleyberg in Saxony. Its colour was white, and its form stalactitical. Specific gravity 3·584. Before the blow-pipe it became yellow; and when exposed to the heat of the blue flame was gradually dissipated. Dissolved with effervescence in sulphuric acid; and when heated lost about ¼th of its weight. It yielded

71·4 oxide of zinc
13·5 carbonic acid
15·1 water

100·0

Mr Smithson considers it as composed of

60 hydrate of zinc
40 carbonate of zinc

100 *

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* See *Phil. Trans.* 1803.

Sp. 3. *Sulphate of Zinc.*

This salt is usually in a state of solution, and therefore belongs properly to mineral waters. Its properties have been described in the First Part of this Work.

ORDER XII. ORES OF BISMUTH.

BISMUTH occurs usually in veins in primitive rocks. It is said also to have been observed disseminated in wacke. It is usually accompanied by the ores of cobalt. Its ores are not abundant. They exist in much greater quantity in Saxony than in any other country; but they are found likewise in Sweden, France, and Cornwal. The following Table will serve to show how little diversified are the ores of this metal.

Table of the species.

- I. ALLOYS
  - 1. Native bismuth
- II. SULPHURETS
  - 1. Common
  - 2. Cupreous
- III. OXIDES
  - 1. Bismuth ochre

Bismuth, like gold, platinum, and silver, occurs most commonly in the state of metal.

GENUS I. ALLOYS.

Sp. 1. *Native Bismuth*[*].

This mineral, which is found at Schneeberg, Johan-

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[*] Kirwan, ii. 264.—Brochant, ii. 343.—Hauy, iv. 184.—Jameson, ii. 392.

Sulphurets.

georgenstadt, &c. in Germany, has commonly the form of small plates lying above one another. Sometimes it is crystallized in four-sided tables, indistinct cubes, and truncated tetrahedrons. Its primitive form is the regular octahedron.

Colour silver white inclining to red; surface often tarnished red, yellow, or purple. Internal lustre 4, metallic. Fracture perfect, foliated. Fragments indeterminate, blunt-edged. In granular distinct concretions. Soft. Sectile. Opaque. Frangibility 4. Specific gravity 9·022 * to 9·57 †. Exceedingly fusible. Before the blow-pipe gives a silvery white bead, and at last evaporates in a yellowish white smoke, which is deposited on the charcoal.

GENUS II. SULPHURETS.

Sp. 1. *Common Sulphuret* ‡.

This ore, which is found in Sweden, Saxony, and Bohemia, occurs sometimes in amorphous masses, and sometimes in needleform crystals.

Colour light lead grey. Powder black and shining. Internal lustre of the foliated 4; of the radiated 3, metallic. Lustre metallic, 2 to 3. Streak obscurely metallic. Fracture foliated; sometimes radiated. The foliated in granular distinct concretions. Soils. Hardness 5. Brittle. Frangibility 4. Specific gravity 6·131 § to 6·4672 ‖. When held to the flame of a

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* Brisson. † Kirwan.

‡ Kirwan, ii. 266.—Sage, *Mem. Par.* 1782, p. 307.—Brochant, ii. 346.—Hauy, iv. 190.—Jameson, ii. 395.

§ Kirwan. ‖ Brisson.

candle, it melts with a blue flame and sulphureous smell. Before the blow-pipe emits a reddish yellow smoke, which adheres to the charcoal. This powder becomes white when it cools, and resumes its former colour when the flame is directed upon it[*].

Sp. 2. *Cupreous Sulphuret* [†].

This ore was discovered by Selb in a cobalt mine in Furstenberg, where it composes a vein about a yard wide. Colour steel grey, but by exposure to the air it acquires a reddish or bluish tarnish. Massive. Lustre 2, metallic. Fracture small-grained uneven. Gives a dull blackish streak. Soft. Sectile. Heavy.

The following Table exhibits a view of the constituents of the two preceding species, according to the analyses hitherto made:

	Sulphuret.		Cupreous Sulphuret.
	‡	§	‖
Bismuth	60	95	47·24
Sulphur	40	5	12·58
Copper			34·66
Loss			5·52
	100	100	100

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[*] Gillet, *Jour. de Min.* No. xxxii. 585.

[†] Klaproth, Gehlen's *Jour.* ii. 187, and *Beitrage*, iv. 91.

[‡] Sage.

[§] Klaproth, *Beitrage*, i 256. But the specimen examined was not common sulphuret. It had been described by Baron Born as an alloy of silver and molybdenum.

[‖] Klaproth, Gehlen's *Jour.* ii. 191.

Oxides.

GENUS III. OXIDES.

Sp. 1. *Bismuth Ochre*[*].

THIS ore is extremely rare. It has been observed at Schneeberg and in Bohemia. It is usually disseminated, or at the surface of other minerals. Colour straw yellow; sometimes passing into light yellowish grey and ash grey. Fracture fine-grained uneven; passing into foliated, and into earthy. Lustre of the fine-grained uneven, 1, 2; of the foliated 3; of the earthy 0, adamantine. Opaque. Soft; verging on friable. Not very brittle. Frangibility 4. Specific gravity 4·3711. Easily reduced and volatilized by the blowpipe on charcoal. Dissolves in acids with effervescence. Its constituents, according to the analysis of Lampadius, are as follows:

Oxide of bismuth	86·3
Oxide of iron	5·2
Carbonic acid......	4·1
Water...............	3·4
	99 †

ORDER XIII. ORES OF ANTIMONY.

THE ores of antimony occur almost always in veins, and affect the primitive and transition mountains. By far the most abundant, and the only ore wrought for metallurgic purposes, is the sulphuret. Antimony ores

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[*] Kirwan, ii. 265.—Brochant, ii. 348.—Jameson, ii. 397.

[†] *Handbuch*, p. 287.

occur in considerable quantities in different parts of Sweden, Norway, Germany, France, Britain, &c. The following Table exhibits the different states in which this metal has hitherto been found in nature:

Table of the Species.

I. ALLOYS
    Native
II. SULPHURETS
    1. Grey ore of antimony
    2. Black ore of antim.
III. OXIDES
    1. White oxide
    2. Red ore of antim.
    3. Antimony ochre

GENUS I. ALLOYS.

Sp. 1. *Native Antimony* [*].

THIS mineral was first discovered by Swab at Sahlberg in Sweden in 1748. It has been since observed in two other places, at Allemont in France, and at Andreasberg in the Hartz. It occurs massive and in kidneyform lumps. Colour tin white. Lustre 4, metallic. Fracture perfect foliated with a fourfold cleavage. Fragments sometimes rhomboidal, usually indeterminate, blunt-edged. In granular, and sometimes in lamellar distinct concretions. Rather sectile. Frangibility 4. Hardness 6. Specific gravity 6·720 [†]. Before the blow-pipe melts and evaporates, depositing a white oxide of antimony. A specimen from Andreasberg, analysed by Klaproth, consisted of

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[*] Kirwan, ii. 245.—Brochant, ii. 367.—Hauy, iv. 252.—Jameson, ii. 415.

[†] Klaproth, iii. 170.

Sulphurets.

98·00 antimony
1·00 silver
0·25 iron

99·25 *

GENUS II. SULPHURETS.

Sp 1. *Grey Ore of Antimony* †.

THIS ore, which is the most common, and indeed almost the only ore of antimony, occurs both massive, disseminated, and crystallized. Its crystals are four-sided prisms, somewhat flattened, whose sides are nearly rectangles, terminated by short four-sided pyramids, whose sides are trapeziums ‡. Sometimes two of the edges are wanting, which renders the prism six-sided §. The primitive form of the crystals not yet determined. It is divided into four subspecies.

Subspecies 1. *Compact.* Colour light lead grey, surface often tarnished, and then it is blue or purplish. Massive and disseminated. Internal lustre 3, 2, metallic. Fracture fine-grained uneven. Fragments indeterminate, blunt-edged. Seldom in small granular distinct concretions. Soft. Frangibility 4. Soils. Streak more shining. Specific gravity 4·368. The most uncommon of the subspecies.

Subspecies 2. *Foliated.* Colour as the preceding. Massive and disseminated. Internal lustre 3, 4, me-

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* *Beitrage*, iii. 272.

† Kirwan, ii. 247.—Brochant, ii. 371.—Hauy, iv. 264.—Jameson, ii. 417.

‡ Rome de Lisle, iii. 49.

§ Ibid.—See also Hauy, *Jour. de Min.* No. xxxii. 606.

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tallic. Fracture foliated; sometimes passing into broad radiated. Cleavage single. Fragments indeterminate. In granular distinct concretions; coarse and fine, and usually longish. Soft. Not particularly brittle. Frangibility 4. Specific gravity 4·368.

Subspecies 3. *Radiated.* Colour light lead grey, often tarnished. Massive, disseminated, and crystallized in six and four sided prisms. Surface of crystals streaked, longitudinally, and usually shining. Internal lustre 4 to 2, metallic. Fracture radiated. Fragments indeterminate; sometimes splintery. In thin imperfect columnar, and longish granular distinct concretions. Soft. Not particularly brittle. Frangibility 4. Specific gravity 4·2 to 4·5.

Subspecies 4. *Plumose.* Colour between blackish lead grey and steel grey. Massive, but usually in thin capillary crystals. External lustre 3; internal 1, metallic. Fracture delicate promiscuous fibrous. Fragments indeterminate, blunt-edged. Opaque. Very soft. Not particularly brittle. Frangibility 4. Heavy.

Sp. 2. *Black Ore of Antimony* *.

This ore is found in Cornwal. Colour iron black. Crystallized in four-sided rectangular tables, truncated on the edges. Planes of the crystals smooth. Internal lustre 3, metallic. Fracture small conchoidal. Fragments indeterminate. Soft. Rather sectile. Heavy.

These ores have not yet been subjected to chemical analysis, if we except radiated grey antimony, which yielded to Bergman,

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* Jameson, ii. 425.

Antimony	74
Sulphur	26
	100

GENUS III. OXIDES.

Sp. 1. *White Ore of Antimony* *.

THIS ore, which has been found in Bohemia and Dauphiny, is sometimes in quadrangular tables and cubes; sometimes in acicular crystals grouped like zeolites, and sometimes in prisms. Colour passes from snow white to yellowish white. Internal lustre 3, between pearly and adamantine. Fracture foliated. Single cleavage; sometimes radiated. Fragments indeterminate. In granular and columnar distinct concretions. Transparency 2. Soft. Rather sectile. Heavy. Melts easily by the flame of a candle, and emits a white vapour †. Before the blow-pipe decrepitates; when powdered and just ready to melt, it evaporates and leaves a white powder around. Between two pieces of coal it is reducible to a metallic state. This ore had been taken for a muriate of antimony; but Klaproth has lately ascertained it to be a pure white oxide of that metal ‡.

Sp. 2. *Ochre of Antimony* §.

This mineral is uncommon. It has been found at

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* Kirwan, ii. 251.—Brochant, ii. 381.—Hauy, iv. 273.—Jameson, ii. 428.

† Hauy, *Jour. de Min.* No. xxxii. 609.

‡ Klaproth, iii. 183.

§ Kirwan ii. 252.—Brochant, ii. 383.—Jameson, ii. 431.

Braunsdorf near Freyberg, and in Hungary. Sometimes massive, sometimes covering grey ore of antimony. Colour straw yellow. Lustre 0. Fracture earthy. Soft. Not particularly brittle, nor heavy. Infusible before the blow-pipe; but emits a white smoke, and is volatilized. With borax it froths, and is partly reduced to the metallic state.

Sp. 3. *Red Ore of Antimony*[*].

This ore occurs at Braunsdorf in Saxony, and Kremnitz in Hungary, and at Allemont in France. It is usually in the state of capillary crystals grouped together. Colour cherry red. Lustre 2, adamantine. Fracture fibrous. Fragments wedge-shaped and splintery. In coarse and small longish granular distinct concretions. Opaque. Streak similar. Very soft. Not very brittle. Frangibility 4. Specific gravity 3·75[†] to 4·09[‡]. Before the blow-pipe melts, emits a slight smell of sulphur, and is volatilized. When heated in muriatic acid it emits sulphureted hydrogen gas, holding hydrosulphuret of antimony in solution. When heated to redness a little carbonic acid is emitted, some glass of antimony is formed, and the greatest part assumes the form of oxide of antimony. It yields 67½ *per cent.* of antimony.

The following Table exhibits a view of the constituents of such of the preceding species as have been analysed:

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[*] Kirwan, ii. 250.—Brochant, ii. 379.—Hauy, iv. 276.—Jameson, ii, 426.

[†] Lametherie.

[‡] Klaproth, iii. 179.

Oxides.
Constituents.

	White Ore.		Red Ore.
	*	†	‡
Oxide of antimony	100	89	78·3
Sulphur			19·7
Silica		8	
Loss		3	2·0
	100	100	100

ORDER XIV. ORES OF TELLURIUM [§].

HITHERTO tellurium has only been found in Transylvania. It occurs in the mines of Fatzbay, Offenbanya, and Nagyag; which are considered as gold mines, because they contain less or more of that metal. Tellurium has been found only in the metallic state, combined with gold, silver, or lead. There are four ores of it, distinguished from each other since the analysis of Klaproth; namely,

I. ALLOYS.

1. Native tellurium
2. Graphic ore
3. White or yellow ore
4. Foliated or black ore

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[*] Klaproth, *Beitrage*, iii. 183.

[†] Vauquelin, Hauy, iv. 274. Under the oxide of antimony a little iron is included.

[‡] Klaproth, *Beitrage*, iii. 132.

[§] Klaproth, iii. 1.

GENUS I. ALLOYS.

Sp. 1. *Native Tellurium* [*].

Aurum Paradoxicum, Problematicum.

THIS mineral has been found only in the mine of Mariahilf, in the Fatzbay mountains in Transylvania. It occurs massive and disseminated; and also crystallized, it is said. Lustre 3, metallic. Fracture foliated. In small granular distinct concretions. Soft. Frangibility 4. Specific gravity 5·73 to 6·115 [†].

Sp. 2. *Graphic Ore* [‡].

Schrifterz—Aurum Graphicum.

This species has been found only in the mine called Franciscus, at Offenbanya in Transylvania. It is usually in the state of small six-sided prismatic crystals, grouped together in rows, and often disposed in such a way as to have a resemblance to written characters. Colour light steel grey. External lustre 4; internal 2, metallic. Fracture fine-grained uneven. Fragments sharp-edged. Soft. Brittle. Specific gravity 5·723.

Sp. 3. *White* or *Yellow Ore* [||]—*Gelberz* of Klaproth. This ore has been found only in the mine of Nagyag

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[*] Klaproth, iii. 2.—Brochant, ii. 480.—Hauy, iv. 325.—Jameson, ii. 513.

[†] Klaproth.

[‡] Klaproth, iii. 16.—Brochant, ii. 482.—Hauy, iv. 327.—Jameson, ii. 515.

[||] Klaproth, iii. 20.—Brochant, ii. 484.—Jameson, ii. 518.

in Transylvania. It seems to bear a strong resemblance to the last species. Found disseminated, or crystallized in small four-sided prisms. Colour silver white, passing into brass yellow. Lustre of the principal fracture 4, 3; of the cross fracture 2, metallic. Fracture in one direction foliated, in another small-grained uneven. Soft. Somewhat sectile. Specific gravity 10·678.

Were we to suppose the lead accidentally mixed, the composition of this ore would agree with that of the last.

Sp. 4. *Foliated* or *Black Ore* *.

This ore is found at Nagyag, and is wrought for the gold which it contains. It occurs in plates, or in six-sided tables somewhat elongated. Colour between lead grey and iron black. External lustre 4; internal 2, metallic. Fracture foliated. Fragments tabular. In granular distinct concretions. Stains a little. Soft. Leaves slightly flexible. Specific gravity 8·918. Soluble in acids with effervescence.

The following Table exhibits a view of the constituents of these ores, according to the analysis of Klaproth.

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* Klaproth, iii. 26.—Brochant, ii. 486.—Jameson, ii. 520.

	Native.	Graphic.	Yellow.	Foliated.
	*	†	‡	§
Tellurium	92·55	60	44·75	32·2
Gold	0·25	30	26·75	9·0
Iron	7·20			
Silver		10	8·50	0·5
Lead			19·50	54·0
Copper				1·3
Sulphur			0·50	3·0
	100	100	100	100

ORDER XV. ORES OF ARSENIC.

ARSENIC is scattered in great abundance over the mineral kingdom, accompanying almost every other metal, and forming also sometimes peculiar veins of its own. These veins occur most commonly in primitive mountains, though they are found also, at least some of the species, in floetz rocks.

The following Table exhibits a view of the different ores in which this metal occurs.

I. ALLOYS
    Native arsenic
II. SULPHURETS
    1. Arsenical pyrites
    2. Orpiment
III. OXIDES
    Native oxide.

IV. SALTS
    Arseniate of lime
    ——— copper
    ——— iron
    ——— lead
    ——— cobalt

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* Beitrage, iii. 8. † Ibid. p. 20. ‡ Ibid. p. 25. § Ibid. p. 32.

Sulphurets.

GENUS I. ALLOYS.

Sp. 1. *Native Arsenic* *.

THIS mineral is found in different parts of Germany. It occurs generally in masses of various shapes, kidney-form, botryoidal, &c. Colour light lead grey. Its surface quickly becomes tarnished by exposure to the air, and becomes greyish black. Lustre metallic (when fresh) 3 to 2. Streak bluish grey, metallic and bright. Powder dull and black. Fracture small-grained uneven; sometimes imperfect foliated. In thin curved lamellar distinct concretions. Hardness 7 to 8. Frangibility 6. Sectile. Specific gravity 5·67 † to 5·7249 ‡. Gives an arsenical smell when struck. Before the blow-pipe emits a white smoke, diffuses a garlic smell, burns with a blue flame, gradually evaporates, depositing a white powder. It is always alloyed with some iron §, and often contains silver, and sometimes gold.

GENUS II. SULPHURETS.

Sp. 1. *Arsenical Pyrites* ‖.

THIS mineral is common in different parts of Germany, &c. It occurs massive and disseminated, and very often crystallized. The primitive form of its crystals is a rhomboidal prism, the angles of whose base are 103° 20′

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* Kirwan, ii. 255.—Brochant, ii. 435.—Hauy, iv. 220.—Jameson, ii. 469.

† Kirwan.

‡ Brisson.

§ De Born, *Catal.* of Raab, iii. 194.

‖ Kirwan, ii. 256.—Brochant, ii. 438.—Hauy, iv. 57.—Jameson, ii. 469.

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and 76° 40′. It occurs in this form. Sometimes the prism is terminated by four-sided summits; sometimes its lateral faces are cylindrical. It occurs also in lenticular crystals *. This species is divided into two subspecies.

Subspecies 1. *Common.* Colour of the fresh fracture silver white; by exposure it acquires a yellowish tarnish. Massive; disseminated; and crystallized in oblique four-sided prisms, very acute double four-sided pyramids, irregular cubes, and needles. Lateral faces smooth; those formed by truncation usually streaked. Their lustre is 4. Internal lustre 3, 2, metallic. Fracture coarse and small grained uneven. Fragments indeterminate, blunt-edged. Usually unseparated; sometimes in columnar distinct concretions. Hard. Brittle. Frangibility 2. Specific gravity 5·405 to 6·522. When rubbed emits an arsenical smell.

Subspecies 2. *Argentiferous.* Colour silver white, surface tarnished yellowish. Massive, disseminated, and in small acicular four-sided prisms. External lustre 3; internal 2, 1, metallic. Fracture fine-grained uneven. Fragments indeterminate. Has sometimes a tendency to fine granular distinct concretions. In other respects agrees with the preceding.

Sp. 2. *Orpiment.*

This species is divided into two subspecies; namely, *red orpiment* and *yellow orpiment*.

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* A description of the different forms in which arsenical pyrites occurs, with figures of each, is given by Bernhardi in Gehlen's *Jour.* Second Series, iii. 80.

Subspecies 1. *Red Orpiment.—Realgar* *. This mineral is found in Sicily, about Mount Vesuvius, in Hungary, Transylvania, various parts of Germany, &c. It is either massive or crystallized. The primitive form of the crystals is an octahedron with scalene triangles, which seem to be the same with the primitive form of sulphur; and it commonly appears in 4, 6, 8, 10, or 12 sided prisms, terminated by four-sided summits †.

Colour aurora red. Streak lemon or orange yellow. External lustre 3, 4; internal 3, between pearly and adamantine. Transparency from 2 to 3. Hardness 5 to 6. Frangibility 4. Specific graviy 3·3384 ‡. It is an electric *per se*, and becomes negatively electric by friction §. Nitric acid deprives it of its colour. Before the blow-pipe it melts easily, burns with a blue flame and garlic smell, and soon evaporates.

Subspecies 2. *Yellow Orpiment* ‖. This ore, which is found in Hungary, Wallachia, Georgia, and Turkey in Asia, is either massive or crystallized. The crystals are confused, and their figure cannot be easily determined; some of them appear octahedrons, and others minute four-sided prisms. Colour lemon yellow. Streak similar. Internal lustre 4, between adamantine and semimetallic. Fracture curve-foliated. Plates

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* Kirwan, ii. 261.—Bergman, ii. 297.—Brochant, ii. 447.—Hauy, iv. 228.—Jameson, ii. 477.

† Romé de Lisle, iii. 34.—Hauy, iv. 229.

‡ Brisson.

§ Hauy, *Jour. de Min.* No. xxxii. 612.

‖ Kirwan, ii. 260.—*Allerti de Auripigmento.*—Scopoli in anno 5to *Hist. Nat.* p. 59.—Bergman, ii. 297.—Brochant, ii. 444.—Hauy, iv. 234.—Jameson, ii. 481.

flexible, but not elastic. Occurs in large and small granular distinct concretions. Transparency 2, 4. Hardness 4. Sectile. Specific gravity from 3·048[*] to 3·521[†]. Effervesces with hot nitric acid. Burns with a bluish white flame. Before the blow-pipe melts, smokes, and evaporates, leaving only a little earth and some traces of iron. Becomes electrified minus when rubbed.

Hitherto the first only of these species has been analysed. Both the subspecies of the second, according to Proust, are sulphurets of arsenic. The following Table exhibits the constituents of common arsenic pyrites, according to the different analyses hitherto made.

	[‡]	[§]	[‖]
Arsenic	53·0	42·1	48·1
Iron	19·7	57·9	36·5
Sulphur	15·3		15·4
Silica	12·0		
	100	100	100

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[*] Kirwan. [†] Gellert. [‡] Vauquelin, *Jour. de Min.* No. xix. p. 3. [§] Lampadius, *Handbuch*, p. 310.

[‖] This is the result of my analysis. The arsenic, however, is stated partly by estimate, as I could not succeed completely in separating it in a state of purity. Lampadius denies that this ore contains sulphur. The specimens which he examined must have been very different from mine, as in my trials a portion of sulphur (small indeed) always separated when the ore was dissolved in nitro-muriatic acid: Neither could I succeed, as he did, in obtaining the arsenic pure by sublimation.

Oxides.

GENUS III. OXIDES.

Sp. 1. *Native Oxide* *.

THIS ore is found in various parts of Germany, Hungary, &c. either in powder, or massive, or crystallized in prismatic needles. It is very uncommon. Colour white or grey, often with a tint of red, yellow, green, or black. Lustre common, 1 to 2. Transparency 1 to 0; when crystallized, 2. Texture earthy. Hardness 6. Brittle. Specific gravity 3·7 †. Soluble in hot diluted nitric acid without effervescence. Soluble at 60° Fahrenheit in 80 times its weight of water. Before the blow-pipe sublimes, but does not inflame. Tinges borax yellow.

GENUS IV. SALTS.

Sp. 1. *Arseniate of Lime* ‡.—*Pharmacolite.*

THIS salt has been hitherto found only in the mine Sophia, near Wittichen in Suabia, where it occurs in the rents of a granite rock, accompanied by cobalt ore. Colour reddish and snow white. Occurs as a coating, and in delicate capillary crystals. Internal lustre 1, silky. Fracture delicate radiated. Fragments indeterminate, and sometimes wedge-shaped. In granular distinct concretions. Transparency 1. Very soft.

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* Kirwan, ii. 258.—Bergman, ii. 285.—Brochant, ii. 450.—Hauy, iv. 225.

† Kirwan.

‡ Brochant, ii. 523.—Hauy, ii. 293.—Klaproth, iii. 280.—Jameson, ii. 483.

Frangibility 4. Soils. Specific gravity 2·64 * to 2·536 †. According to the analysis of Klaproth, it is composed of

Arsenic acid	50·54
Lime	25·00
Water	24·46
	100·00 ‡

Sp. 2. Arseniate of copper.—See Class IV. Order VI. Genus IV.

Sp. 3. Arseniate of iron.—See Class IV. Order VII. Genus IV.

Sp. 4. Arseniate of lead.—See Class IV. Order X. Genus III.

Sp. 5. Arseniate of Cobalt.—See Class IV. Order XVI. Genus IV.

ORDER XVI. ORES OF COBALT.

COBALT ores occur both in primitive, transition, and floetz mountains. They are not very abundant; and for that reason cobalt is more valuable than many of the other metals which have been already treated of. They are commonly accompanied by nickel, bismuth, or iron. They are most abundant in Germany, Sweden, Norway, and Hungary; they have been found also in Britain and France, but not in any great quantity.

Few of the ores of cobalt have been analysed with precision; hence the confusion which still obscures

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* Klaproth.

† Sebb.

‡ *Beitrage*, iii. 281.

their mineralogical arrangement and description. The following Table exhibits what are at present considered as the different species of these ores, arranged according to their supposed composition :

Alloys.

I Alloys
  1. White cobalt ore
  2. Glance cobalt
  3. Grey cobalt ore
II. Oxides
  1. Black cobalt ochre
  2. Brown cobalt ochre
  3. Yellow cobalt ochre
III. Salts
  1. Arseniate of cobalt
  2. Sulphate

GENUS I. ALLOYS.

Sp. 1. *White Cobalt Ore*[*].

This is the most common species of cobalt ore, and indeed almost the only ore wrought for metallurgic purposes.

Colour silver white, slightly inclining to reddish; acquires a greyish tarnish. Commonly massive, or in particular shapes ; sometimes crystallized in cubes or dodecahedrons. Crystals usually small ; faces smooth. External lustre 4 ; internal 3, 2, metallic. Fracture fine grained uneven ; sometimes radiated and imperfect foliated, with a threefold cleavage. Fragments indeterminate, rather blunt-edged. Usually unseparated ; sometimes in granular distinct concretions. Semihard. Brittle. Frangibility 2. Heavy. When struck with steel emits an arsenical smell.

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[*] Jameson, ii. 432.

Sp. 2. *Glance Cobalt* *.

Found in beds in mica slate, at Tunaberg in Sweden, from which most of the crystallized specimens are brought; at Los and at Modum, in Norway; and likewise at Giern, in Silesia. Colour tin white; sometimes tarnished grey. Massive, in various particular forms, and crystallized in cubes and octahedrons. Surface of crystals smooth and splendent. Internal lustre 2, metallic. Fracture fine and coarse grained uneven; often passes into imperfect foliated and into radiated. Fragments indeterminate, sharp-edged; sometimes wedge-shaped. In granular and lamellar distinct concretions. Semihard. Brittle. Frangibility 3. Specific gravity 6·4509 †.

Sp. 3. *Grey Cobalt Ore* ‡.

This ore, which is rarer than the preceding, occurs in various parts of Germany, Cornwal, France, &c. Colour light steel grey, inclining to white; but when exposed to the air, is soon tarnished greyish black. Massive, disseminated, tubiform, and specular. Internal lustre 1, 2, metallic. Fracture even; sometimes passing into large flat conchoidal, and into fine grained uneven. Fragments indeterminate, pretty sharp-edged. Seldom in lamellar distinct concretions. Streak similar. Semihard. Very brittle. Frangibility 4. Specific gravity 5·571 §.

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* Jameson, ii. 432.

† Hauy.

‡ Jameson, ii. 434.

§ Kirwan.

Oxides.

The two first of the preceding ores seem to resemble each other so closely as to form at most only subspecies of the same species. The following Table exhibits the analyses hitherto made:

	Glance Cobalt.		Grey Ore.
	*	†	‡
Cobalt	36·7	44·0	20
Arsenic	49·0	55·5	33
Iron	5·6		24
Sulphur	6·5	0·5	
Loss	2·2		23
	100	100	100

GENUS II. OXIDES.

Sp. 1. *Black Cobalt Ore*[§].

THIS ore, which occurs in different parts of Germany, is either in the form of a powder or indurated. Hence it is divided into two subspecies.

Subspecies 1. *Earthy.* Colour bluish black; sometimes brownish black. Composed of dull dusty particles, which soil very little; sometimes loose. Lustre of streak 3. Feels meagre. Light, almost swimming. Before the blow-pipe gives a white smoke, which has an arsenical smell, and colours borax blue.

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[*] Tassaert, *Ann. de Chim.* xxviii. 100.

[†] Klaproth, *Beitrage*, ii. 307.

[‡] Klaproth's *Cornwal*, p. 61.

[§] Kirwan, ii. 275.—Brochant, ii. 396.—Hauy, iv. 214.—Jameson, ii. 438.

Subspecies 2. *Indurated.* Colour usually bluish black. Massive, disseminated, and as a coating. External lustre scarce 1; internal 0. Fracture fine earthy. Fragments indeterminate, blunt-edged. Lustre of streak 8, resinous. Very soft. Rather sectile. Frangibility 4. Specific gravity 2·019 to 2·425 *. Considered as pure oxide of cobalt, but has not been analysed.

Sp. 2. *Brown Cobalt Ochre* †.

This ore seems peculiar to the floetz mountains. It is found in Saxony and Spain. Colour liver brown; sometimes passing into yellowish brown, and into black. Massive and disseminated. Lustre 0. Fracture fine earthy. Fragments indeterminate, blunt-edged. Streak similar, but shining. Very soft. Sectile. Frangibility 4. Light.

Sp. 3. *Yellow Cobalt Ochre* ‡.

This ore occurs in the same situation as the preceding, but is rarer. Colour dirty straw yellow; sometimes passing into yellowish grey. Massive. Internal lustrs 0. Fracture fine earthy. Fragments indeterminate, blunt-edged. Streak shining. Soft, passing into friable. Sectile. Frangibility 4. Light.

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* Gellert.

† Jameson, ii. 441.

‡ Ibid. ii. 443.

Salts.

GENUS III. SALTS.

Sp. 1. *Arseniate of Cobalt* *—*Red Cobalt Ore.*

THIS species, which accompanies several of the other ores of cobalt, has been divided into two subspecies.

Subspecies 1. *Cobalt Crust—Earthy Red Cobalt Ochre.* Colour peach blossom red. Seldom massive; often in velvety coatings. Lustre 1, 0. Fracture fine earthy. Fragments indeterminate, blunt-edged. Scarcely soils. Streak shining. Very soft. Light.

Subspecies 2. *Cobalt Bloom—Radiated Red Cobalt Ochre.* Colour peach blossom red; often cochineal and crimson red, pearl grey, greenish grey. Massive, disseminated, reniform, and crystallized in short needles, acute double six-sided pyramids, rectangular four-sided prisms. External lustre 3, 4; internal 3, 2, pearly. Fracture radiated. Fragments splintery and wedge-shaped; sometimes in thin columnar distinct concretions, collected into coarse granular distinct concretions. Transparency 2, 1. Streak similar. Soft. Not particularly brittle. Rather sectile. Frangibility 4. Light.

Before the blow-pipe becomes grey, and emits a garlic smell, but without smoke. Tinges borax blue.

Sp. 2. *Sulphate of Cobalt.*

This salt has been found in Neusohl in Hungary, in the form of transparent stalactites of a red colour,

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* Klaproth, ii. 278.—Brochant, ii. 403.—Hauy, iv. 216.—Jameson, ii. 444.

Some mineralogists considered these stalactites as sulphate of manganese ; others as sulphate of cobalt. Klaproth found, by analysis, that the latter opinion is the true one [*].

ORDER XVII. ORES OF MANGANESE [†].

ORES of manganese occur both in primitive and transition mountains. They are very common, having been found abundantly in Germany, France, Spain, Britain, Sweden, Norway, Siberia, and other countries.

Hitherto manganese has only been found in the state of oxide. La Perouse, indeed, suspected that he had found it in a metallic state ; but the quantity was too minute to admit of decisive experiments. The following Table exhibits the ores of this metal which have been described :

I. OXIDES
  1. Grey ore
  2. Black ore
II. SALTS
  1. Red ore or carbonate

GENUS I. OXIDES.

Sp. 1. *Grey Ore* [‡].

THIS mineral is found in great abundance in different

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[*] *Beitrage*, ii. 320.

[†] Pott, *Miscelan. Berolens.* vi. 49.—Margraff, *Mem. Berlin*, 1773, p. 3. —La Perouse, *Jour. de Phys.* xvi. 156, and xv. 67. and xxviii. 68.—Sage, *Mem. Par.* 1785, p. 235.

[‡] Kirwan, ii. 291.—Brochant, ii. 414.—Hauy, iv. 243.—Jameson, ii. 452.

parts of the earth. It is divided into four subspecies by Werner.

Subspecies 1. *Radiated Grey Ore.* Colour steel grey. Found massive and disseminated, and crystallized in four-sided prisms, either terminated by four-sided or by two-sided summits. The faces of the prisms are longitudinally streaked. Internal lustre 2, 3, metallic. Fracture radiated. Surface of fracture streaked. Fragments splintery or wedge-shaped. In granular distinct concretions. Streak similar. Stains. Soft. Brittle. Frangibility 2. Specific gravity from 3·7076 to 4·756.

Subspecies 2. *Foliated Grey Ore.* Colour steel grey. Found massive, disseminated, and crystallized in longish rhombs. Internal lustre, 2, 3, metallic. Fracture foliated. Fragments indeterminate, blunt-edged. Streak black and dull. Stains. Soft. Brittle. Frangibility 3. Specific gravity 3·742.

Subspecies 3. *Compact Grey Ore.* Colour steel grey. Found massive and disseminated. External lustre 0; internal 2, metallic. Fracture even; sometimes inclining to flat conchoidal. Fragments indeterminate, not very sharp-edged. Usually unseparated; sometimes in thick lamellar distinct concretions. In other respects resembles the preceding.

Subspecies 4. *Earthy Grey Ore.* Colour dark steel grey, inclining a little to bluish. Massive. Composed of delicate scaly particles, which have a glimmering metallic lustre. Soils strongly. More or less cohering. Feels fine but meagre. Moderately heavy.

The grey ore of manganese, before the blow-pipe, becomes brownish black, but does not melt. Tinges borax violet.

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Sp. 2. *Black Ore of Manganese* *.

This ore is rare, and usually occurs along with grey antimony ore. Colour between brownish and greyish black. Found massive, or disseminated, or crystallized in octahedrons. Surface of the crystals smoooth and shining. Internal lustre 2. Fracture imperfect foliated. Fragments indeterminate, blunt-edged. In small granular distinct concretions. Streak reddish brown. Opaque. Semihard. Brittle. Heavy.

The following Table exhibits a view of the constituents of these species, according to the analyses hitherto made :

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* Brochant, ii. 424.—Jameson, ii. 460.

Oxides.

	Radiated Grey Ore.					Compact Grey Ore.				Black Ore.		
	*	*	†	†	†	‡	‡	‡	‡	‖	§	¶
Ox. of mangan	92·75	99·25	83·5	82	86	68	67	83·7	72	82	85	60
Oxide of iron	7		2		3	18	13·5					
Charcoal					1·5			0·4				
Lime				8·5		7	6		7			
Barytes			1·5	2		4	5	14·7	9			
Silica			7·5	7	5	3	7	1·2	6			25
Carbonic acid										5		
Sulphur										11	15	
Water		0·5										13
Loss	0·25	0·25	5·5	0·5	4·5		1·5		6	2		2
	100	100	100	100	100	100	100	100	100	100	100	100

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* Klaproth, *Beitrage*, iii. 303. The specimen was from Ilefeld in the Hartz.

† Cordier and Beaunier, *Jour. de Min.* No. lviii. p. 778. The first specimen yielded 38 *per cent.* of oxygen, the second 36·5, and the third 42. The lime in the second specimen was in the state of carbonate.

‡ Cordier and Beaunier, Ibid. The first specimen, from St Micaud, yielded 33 *per cent.* of oxygen; the second, from Perigueux, 17 *per cent.* The lime in these was contaminated with some magnesia, iron, and manganese. The third specimen, from Romaneche, yielded 33·7 *per cent.* of oxygen; the fourth, from Laveline, 17 *per cent.* The lime in this last was in the state of carbonate.

‖ Klaproth, *Beitrage*, iii. 42. The specimen analysed was from Transylvania, and had been called *black blende.*

§ Vauquelin, Gehlen's *Jour.* Second Series, ii. 34.

¶ Klaproth, *Beitrage*, iv. 137 The specimen analysed was from Dalecarlia, and differed in its properties somewhat from the *black ore* described in the text.

Genus II. Salts.

Sp. 1. *Carbonate—Red Ore of Manganese* [*].

This ore has been found in Transylvania in the mines of Nagyag, and is said also to occur in Norway and France. Massive. Colour pale rosy red; by withering becomes light yellowish brown. Fracture even. Lustre 6. Transparency 1. Hardness 8. Brittle. Frangibility 4. Specific gravity 3·233. The constituents of this ore, according to the analysis of Lampadius, are as follows:

Oxide of manganese	48
Carbonic acid	49·2
Oxide of iron	2·1
Silica	0·9
	100·2[†]

Order XVIII. ORES OF CHROMIUM.

Scarcely any thing precise is known respecting the situation of the ores of chromium. Those hitherto observed would appear to occupy veins in primitive formations. The following Table exhibits a list of the species at present known:

I. Alloys
  1. Needle ore
II. Oxides
  1. Chrome ochre

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[*] Kirwan, ii. 297.—Napion, *Mem. Turin*, iv. 303.—Brochant, ii. 425.—Jameson, ii. 463.

[†] Jameson, *Miner.* ii. 464.

III. Salts.
  1. Chromate of iron
  2. Chromate of lead.

Genus I. Alloys.

Sp. 1. *Needle Ore**.

This ore has been found in Siberia. Colour dark steel grey, but becomes readily tarnished yellow on the surface. In imbedded acicular crystals. Internal lustre 3, metallic. Fracture small-grained uneven, sometimes approaching conchoidal. Soft, approaching semi-hard. Not particularly brittle. Heavy.

Genus II. Oxides.

Sp. 1. *Chrome Ochre*†.

Occurs along with the preceding species. Colour verdegris green, passing into straw yellow. Massive, disseminated, and in membranes. Lustre 0. Fracture sometimes uneven, sometimes fine earthy. Soft. Not particularly heavy.

Genus III. Salts.

Sp. 1. *Chromate of Iron*‡.

This mineral, which has been found near Gassin in the department of Var in France, and in Siberia, is in irregular masses.

Colour brown, not unlike that of brown blende.

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* Jameson, ii. 522. † Ibid. ii. 523.

‡ Brochant, ii. 554.—Hauy, iv. 129.

Powder ash grey. Lustre slightly metallic. Hardness sufficient to scratch glass. Specific gravity 4·0326. Does not melt before the blow-pipe *per se;* but melts with borax, and forms a fine green bead. Insoluble in nitric acid. Melted with potash and dissolved in water, the solution assumes a beautiful orange yellow colour. Its constituents are as follows.

	*	†	‡
Oxide of chrome	43·0	53	55·5
Oxide of iron	34·7	34	33·0
Alumina	20·3	11	6·0
Silica	2·0	1	2·0
Loss		1	2·0
	100	100	100

Sp. 2. *Chromate of Lead.*—See Order X. Genus III.

ORDER XIX. ORES OF URANIUM.

THE ores of uranium occur in Saxony, Bohemia, Norway, Cornwal, France, and are found in veins in primitive mountains. Hitherto it has been observed only in the state of oxide. The following are the species at present known:

I. OXIDES
  1. Protoxide or pitch ore
  2. Green mica or green oxide
  3. Uran ochre or peroxide.

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* Vauquelin, *Jour. de Min.* No. lv. 523. Specimen from the Var.

† Laugier, *Phil. Mag.* xxiv. 7. Specimen from Siberia.

‡ Klaproth, Gehlen's *Jour.* Second Series, i. 192.

GENUS I. OXIDES.

Sp. 1. *Pitch Ore.—Pechblende* [*].

THIS ore, which has been found at Johanngeorgenstadt in Saxony, Joachimsthal in Bohemia, and Konigsberg in Norway, is either massive or disseminated.

Colour velvet black or dark greyish black. Streak similar. Internal lustre 3, 2, resinous. Fracture imperfect flat conchoidal. Fragments indeterminate, sharp-edged. Occurs in thick curved lamellar, and in coarse angulo-granular distinct concretions. Soft. Very brittle. Specific gravity from 6·3785 [†] to 7·5, and even higher [‡]. Imperfectly soluble in sulphuric and muriatic acids; perfectly in nitric acid and aqua regia. Solution wine yellow. Infusible with alkalies in a crucible: infusible by the blow-pipe *per se.* With borax and soda forms a grey opaque slag; with microcosmic salt, a green glass. A specimen of this ore from Joachimsthal, analysed by Klaproth, contained

86·5	uranium
6·0	sulphuret of lead
5·0	silica
2·5	oxide of iron
100·0 [§]	

Sp. 2. *Uran Mica* [‖]*—Green Mica—Chalcolite.*

This substance is found in Cornwal, France, at Jo-

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[*] Kirwan, ii. 305.—Jameson, ii. 505.

[†] Morveau, *Jour. de Min.* No. xxxii. 610.

[‡] Klaproth, *Beitrage*, ii. 197.

[§] *Beitrage*, ii. 321.

[‖] Kirwan, ii. 304.—Hauy, iv. 283.—Brochant, ii. 463.—Jameson, ii. 508.

hanngeorgenstadt, and near Eibenstock and Rheinbreidenbach [*]. It is sometimes in membranes, but more commonly crystallized. Its crystals are rectangular four-sided tables, cubes, and octahedrons.

Colour grass green, passing into emerald green and into siskin green. External lustre 3 to 4; internal 3, 2, pearly. Transparency 2 to 1. Fracture foliated. Hardness 5 to 6. Sectile. Frangibility 4. Specific gravity 3·1212 [†]. Soluble in nitric acid without effervescence. Infusible by alkalies.

Composed of oxide of uranium, with some oxide of copper.

Sp. 3. *Uran Ochre* [‡].

This species, which occurs along with the other ores of uranium, is divided into two subspecies.

Subspecies 1. *Friable.* Colour straw yellow, passing into lemon yellow, into yellowish brown and orange yellow, and sometimes aurora red. Usually coats pitch ore. Friable, and composed of dull dusty particles. Soils feebly. Feels meagre. Not particularly heavy.

Subspecies 2. *Indurated.* Colour as the preceding. Massive and disseminated. Internal lustre 0. Sometimes 1, 2. Fracture small-grained uneven; sometimes passes into earthy, sometimes into small conchoidal. Fragments indeterminate. Opaque. Soft. Brittle. Soils a very little. Specific gravity 3·15 to 3·2438 [§].

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[*] Gmelin.

[†] Champeaux.

[‡] Kirwan, ii. 303.—Brochant, ii. 466.—Jameson, ii. 510.

[§] Lametherie and Hauy.

Sulphurets.

ORDER XX. ORES OF MOLYBDENUM.

GENUS I. SULPHURETS.

Sp. 1. *Common Sulphuret*[*]—*Molybdena.*

THIS ore, which is the only species of molybdenum ore at present known, is found commonly massive; sometimes, however, it is crystallized in hexahedral tables and prisms. Its primitive form, according to Hauy, is a rhomboidal prism with angles of 60° and 120°.

Colour light lead grey. Streak similar. Lustre 4, 3, metallic. Fracture perfect foliated. Lamellæ slightly flexible. Occurs in large and coarse granular distinct concretions. Soft. Frangibility 4. Splits easily. Sectile. Specific gravity 4·569[†] to 4·7385[‡]. Feels greasy; stains the fingers. Marks bluish black. A piece of resin rubbed with this mineral becomes positively electric[§]. Insoluble in sulphuric and muriatic acids; but in a boiling heat colours them green. Effervesces with warm nitric acid, leaving a grey oxide undissolved. Before the blow-pipe, on a silver spoon, emits a white smoke, which condenses into a white powder, which becomes blue in the internal, and loses its colour in the external flame. Scarcely affected by borax or microcosmic salt. Effervesces with soda, and gives it a reddish pearl colour.

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[*] Kirwan, ii. 322.—Scheele's Works, i. 236. French Transl.—Pelletier, *Jour. de Phys.* xxvii. 434.—Ilsemann, Ibid. xxxiii. 292.—Sage, Ibid. 389.—Klaproth and Modeer, *Ann. de Chim.* iii. 120.—Brochant, ii. 432.—Hauy, iv. 289.—Jameson, ii. 465.

[†] Karsten.

[‡] Brisson.

[§] Hauy, *Jour. de Min.* xix. 70.

Composed of about 60 molybdenum
40 sulphur

100 *

ORDER XXI. ORES OF TUNGSTEN.

ORES of tungsten have hitherto been found only in the primitive mountains. They very often accompany tin ores. Hitherto this metal has occurred only in the state of an oxide, constituting two distinct species.

GENUS I. OXIDES.

Sp. 1. *Wolfram* †.

THIS species is found in different parts of Germany, in Sweden, Cornwal, France, and Spain ; and is almost constantly accompanied by ores of tin. It occurs both massive and crystallized. The primitive form of its crystals, according to the observations of Mr Hauy, is a rectangular parallelopiped, whose length is 8·66, whose breadth is 5, and thickness 4·33 ‡. In many cases, the angles, and sometimes the edges, of the crystal are truncated.

Colour between dark greyish and brownish black. Streak reddish brown. Powder stains paper with the

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* Klaproth. This result agrees exactly with the late analysis of this ore by Bucholz. See Gehlen's *Jour.* iv. 603.

† Kirwan, ii. 316.—De Luyart, *Mem. Thoulouse*, ii. 141.—Gmelin, Crell's *Jour.* Eng. Transl. iii. 127. 205. and 293.—La Perouse, *Jour. de Min.* No. iv. p. 23.—Brochant, ii. 456.—Hauy, iv. 314.—Jameson, ii. 488.

‡ *Jour. de Min.* No. xix. 8.

same colour. Lustre external 2; internal 2 to 3, metallic. Fracture foliated. Cross fracture coarse and small grained uneven. Easily separated into plates by percussion. In lamellar distinct concretions. Opaque. Soft. Brittle. Specific gravity from 7·006 * to 7·333 †. Moderately electric by communication. Not magnetic. Infusible by the blow-pipe. Forms with borax a greenish globule, and with microcosmic salt a transparent globule of a deep red ‡.

Sp. 2. *Tungstate of Lime* §.

This ore, which is now scarce, has hitherto been found only in Cornwal, Sweden, and Germany. It is usually massive, sometimes crystallized; and, according to Bournon, the primitive form of its crystals is an acute octahedron; the solid angle at the summit of which measures 48° on the faces, and 64° 22′ on the edges. For a description of the varieties of crystallization, the reader is referred to Bournon ||.

Colour yellowish and greyish white; sometimes verges on snow white; passes into yellowish grey, yellowish brown, and approaches orange yellow. Lustre 3 to 2, vitreous. Transparency 2 to 3. Fracture foliated. Fragments indeterminate, rather blunt-edged. Sometimes in granular distinct concretions. Not particularly brittle. Frangibility 4. Soft. Specific gra-

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* Kirwan. † Hauy.

‡ Vauquelin, *Jour. de Min.* No. xix. 11.

§ Kirwan, ii. 314.—Scheele's Works (French Transl.), ii. 81.—Bergman, Ibid. p. 94.—Crell, *Chem. Annalen*, 1784, 2 Band. 195.—Klaproth, iii. 44.—Jameson, ii. 484.

|| *Jour. de Min.* No. lxxv. p. 167.

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vity 5·8 to 6·0665. Becomes yellow when digested with nitric or muriatic acid. Infusible by the blowpipe. With borax forms a colourless glass, unless the borax exceed, and then it is brown. With microcosmic salt it forms a blue glass, which loses its colour by the yellow flame, but recovers it in the blue flame *.

The following Table exhibits a view of the constituents of these species.

	Wolfram.		Tungsten.	
	†	‡	§	§
Oxide of tungsten	46·9	67	77·75	75·25
Oxide of iron	31·2	18		1·25
Oxide of manganese		6·25		0·75
Lime			17·6	18·70
Silica		1·5	3	1·5
Loss	21·9	7·25	1·65	2·55
	100	100	100	100

ORDER XXII. ORES OF TITANIUM.

HITHERTO titanium has been found almost exclusively in the primitive mountains, the Capracks ¶, the

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* Scheele and Bergman.

† Klaproth's *Cornwall*, p. 71.

‡ Vauquelin and Hecht, *Jour. de Min.* No. xix. p. 11.

§ Klaproth, *Beitrage*, iii. 44.

¶ *Jour. de Min.* No. xii. 51.

Alps[*], and the Pyrenees[†], in Brittanny[‡], and in Cornwall; or in alluvial sand. It has been observed only in the state of an oxide, either pure or combined with iron and silica, and constituting six species.

GENUS I. OXIDES.

Sp. 1. *Menachanite* [§].

THIS substance was first found in the valley of Menachan in Cornwall; and hence was called *menachanite* by Mr Gregor, the discoverer of it. It has been since observed in the island Providence, and in Botany Bay. It is in small grains like gunpowder of no determinate shape, and mixed with a fine grey sand. Colour greyish black. Easily pulverised. Powder attracted by the magnet. Surface rough and glimmering. Internal lustre 3, 2, adamantine; passing into semimetallic. Fracture imperfect foliated. Fragments indeterminate, sharp-edged. Opaque. Soft. Brittle. Streak similar. Specific gravity 4·427. With two parts of fixed alkali it melts into an olive-coloured mass, from which nitric acid precipitates a white powder. The mineral acids only extract from it a little iron. Diluted sulphuric acid mixed with the powder in such a proportion that the mass is not too liquid, and then evaporated to dryness, produces a blue coloured mass. Before the blowpipe does not decrepitate nor melt. It tinges microcos-

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[*] Dolomieu, Ibid. No. xlii. 431. and Saussure, *Voyages*, No. 1894.

[†] *Jour. de Min.* No. xxxii. 614.

[‡] Ibid.

[§] Kirwan, ii. 326.—Gregor. *Jour. de Phys.* xxxix. 72, & 152.—Schmeisser, Crell's *Annals*, Eng. Transl. iii. 252.—Brochant, ii. 468.—Jameson, ii. 491.

mic salt green; but the colour becomes brown on cooling; yet microcosmic salt does not dissolve it. Soluble in borax, and alters its nature in the same manner.

Sp. 2. Octahedrite [*]*—Anatase.*

This mineral has been hitherto found only in Dauphiny. It is always crystallized. The primitive form is an elongated octahedron, whose base is a square: the inclination of the two pyramids is 137°. The summits are sometimes complete and sometimes truncated. Colour from indigo blue passes to reddish and yellowish brown. Faces of the crystals transversely striated. Lustre 4, adamantine. Fracture foliated. Transparency 2, 3. Scratches glass. Brittle, easily broken. Specific gravity 3·8571.

Sp. 3. *Ruthile* [†]*—Red Schorl—Titanite* of Kirwan—*Sagenite* of Saussure—*Nadelstein.*

This ore has been found in Hungary, the Pyrenees, the Alps, and in Brittanny in France. It is generally crystallized. The primitive form of its crystals, according to the observations of Hauy, is a rectangular prism, whose base is a square; and the form of its molecules is a triangular prism, whose base is a right angled isosceles triangle; and the height is to any of the sides of the base about the right angle as $\surd 12$ to $\surd 5$, or nearly as 3 : 2 [‡]. Sometimes the crystals are six-sided, and sometimes four-sided prisms, and often they are implicated together. Sometimes acicular.

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[*] Hauy, iii. 129.—Brochant, ii. 548.—Jameson, ii. 493.

[†] Brochant, ii. 470.—Hauy, iv. 29.—Kirwan, ii. 329.—Jameson, ii. 495.

[‡] *Jour. de Min.* No. xv. 28. and xxxii. 615.

Colour dark blood red, passing into light hyacinth and brownish red. Crystals longitudinally streaked. External lustre 3, 2; of principal fracture 4; of cross fracture 3, 2, adamantine. Principal fracture foliated; cross fracture imperfect small conchoidal. Fragments cubical. Transparency 2. Sometimes shows slender columnar distinct concretions. Hard. Brittle. Streak pale yellow or orange yellow. Frangibility 4. Specific gravity from 4·18 * to 4·2499 †. Not affected by the mineral acids. When fused with carbonate of potash, and diluted with water, a white powder precipitates, heavier than the one employed. Before the blow-pipe it does not melt, but becomes opaque and brown. With microcosmic salt it forms a globule of glass, which appears black; but its fragments are violet. With borax it forms a deep yellow glass with a tint of brown; with soda it divides and mixes, but does not form a transparent glass.

Sp. 4. *Nigrine* ‡.

This species, like menachanite, is found in the alluvial formation. It occurs in Transylvania, Siberia, Ceylon, &c. Colour dark brownish black, passing into velvet black. In larger and smaller angular grains and rolled pieces. External lustre 2; internal 2, adamantine. Principal fracture imperfect straight foliated; cross fracture flat imperfect conchoidal. Fragments indeterminate, sharp-edged. Opaque. Semihard. Brittle. Streak yellowish brown. Specific gravity 4·445 to 4·673 §. Not attracted by the magnet. Infusible

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* Klaproth.

† Vauquelin and Hecht.

‡ Jameson, ii. 499.

§ Klaproth and Lowitz.

before the blow-pipe. With borax melts into a hyacinth red bead.

Sp. 5. *Brown Ore**—*Titanite—Sphene—Rutilite.*

This ore has hitherto been found only near Passau in Bavaria, and at Arendaal in Norway, and near St Gothard. It was discovered by Professor Hunger. It is sometimes disseminated, but more commonly crystallized in four-sided prisms, not longer than one-fourth of an inch. Primitive form a rhomboidal prism.

Colour reddish, yellowish, or blackish brown. Streak and powder grey. Lustre of crystals 3 ; of cross fracture 1, 0 ; of longitudinal fracture 2. Fracture scopiform radiated ; sometimes straight foliated. Cross fracture flat conchoidal. Fragments indeterminate ; sometimes inclining to rhomboidal. Usually in coarse and longish granular distinct concretions. Transparency 1, 0. Hard. Brittle. Frangibility 4. Specific gravity 3·510. Muriatic acid, by repeated digestion, dissolves one-third of it. Ammonia precipitates from this solution a clammy yellowish substance. Infusible by the blow-pipe, and also in a clay crucible ; but in charcoal is converted into a black opaque porous slag.

Sp. 6. *Iserine*†.

This mineral has been found in the sand of a small river in Bohemia called *Iser*. It is in the state of small angular grains and rolled pieces. Colour iron black, bordering on brown. Internal lustre 2, semimetallic. Fracture conchoidal. Opaque. Hard. Brittle. Streak similar. Specific gravity 4·5.

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* Kirwan, ii. 331.—Brochant, ii. 474.—Hauy, iv. 307.—Jameson, ii. 616.

† Brochant, ii. 478.—Jameson, ii. 502.

Oxides.

The following Table exhibits a view of the constituents of these ores, according to the most accurate analysis hitherto made.

Constituents.

	Menachanite.				Ruthile.	Nigrine.				Brown Ore.		Iserine.	
	*	†	‡	§	‖	¶	**	††	‡‡	§§	‖‖	¶¶	**
Oxide of titan.	45	45·25	43·5	40	100	84	53	49	87	33	58	59·1	41·1
—— of iron	46	51·	50·4	49		14	47	35	9			30·1	39·4
Ox. of mangan		0·25	0·9			2		2	3				
Oxygen								14					
Silica		3·50	3·3	11						35	22		16·8
Alumina			1·4										3·2
Lime										33	20		
Uranium oxide												10·2	3·4
Loss	9		0·5									0·6	
	100	100	100	100	100	100	100	100	100	100	100	100	103·9

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[*] Gregor, *Jour. de Phys.* xxxix. 72. and 152. Under the loss a little silica and manganese are included.

[†] Klaproth, *Beitrage*, ii. 231.

[‡] Lampadius, *Handbuch*, p. 322.

[§] Chenevix, Nicholson's *Quarto Jour.* v. 132.

[‖] Klaproth, *Beitrage*, i. 233, and ii. 222. By the analysis of Vauquelin the octahedrite is pure oxide of titanium, while the ruthile contains traces of iron, manganese, and silica, *Jour. de Phys.* lxvi. 345.

[¶] Klaproth, Ibid. ii. 238.

[**] Lowitz, Crell's *Annals*, 1799, i. 183.

[††] Vauquelin and Hecht, *Jour. de Min.* No. xix. 57.

[‡‡] Lampadius, Jameson, ii. 501.

[§§] Klaproth, *Beitrage*, i. 251.

[‖‖] Abelgaard, Hauy, iv. 308.

[¶¶] See Jameson, ii. 503.

[**] By my analysis, *Trans. Edin.* vi. 260. The specimen was from the river Don, Aberdeenshire, and was not quite free from quartz and felspar, and probably contained also a portion of iron sand. For it was originally mixed with iron sand, which was separated by the magnet.

ORDER XXIII. ORES OF COLUMBIUM.

As only a single specimen of the mineral from which columbium was extracted is at present known, there are, properly speaking, no ores of this metal; though it is very likely that they will be met with in North America.

GENUS I. OXIDES.

Sp. 1. *Columbite.*

The only known specimen of this mineral is deposited in the British Museum. It is massive. Colour deep brownish black; internally iron grey. Lustre 3, glassy, passing into the metallic. Longitudinal fracture foliated; transverse fine-grained uneven. Not very hard. Brittle. Opaque. Streak chocolate brown. Specific gravity 5·918. Does not affect the magnetic needle. Composed of

78	columbic oxide
21	oxide of iron
99	

Kielman has, more than a year ago, announced the discovery of columbite in Switzerland by Meyer [*]; but no precise account of this ore has yet reached this country. Ekeberg, from a set of experiments, which he says he made on purpose, has been led to suspect that columbite may be a variety of wolfram; but both the characters of the mineral, and the result of Hatchett's analysis, are against this conclusion [†].

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[*] Gehlen's *Jour.* v. 349.

[†] Ibid. p. 348.

ORDER XXIV. ORES OF TANTALUM.

TANTALUM has hitherto been found only in Sweden, and in small quantities. It has occured in the state of an oxide variously combined. Dr Wollaston has lately ascertained that it is identic with columbium. But till the following species be more accurately described, it would be hazardous to give them new names. I have therefore allowed them to remain for the present as Ekeberg placed them.

GENUS I. OXIDES.

Sp. 1. *Tantalite* *.

This mineral has been found in Finland in the parish of Kimito. It has been long known ; but before the analysis of Ekeberg was mistaken for an ore of tin. Found in irregular crystals, which seem to be octahedrons. Colour between bluish grey and iron black. Surface smooth and glimmering. Internal lustre 3, metallic. Streak blackish grey, approaching brown. Very hard. Not magnetic. Specific gravity 7·953. Composed of the oxides of tantalum, iron, and manganese.

Sp. 2. *Yttrotantalite* †.

This mineral is found in the same place with gadolinite. It is in small kidneyform masses of the size of a hazle-nut. Colour iron black. Fracture uneven.

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* *Jour. de Chim.* iii. 81.

† Ibid. p. 83.

Lustre metallic. Hardness inconsiderable. May be scratched with a knife, and gives a grey-coloured powder. Not magnetic. Specific gravity 5·130. It is composed of the oxides of tantalum, iron, uranium, and tungsten, united to yttria *.

ORDER XXV. ORES OF CERIUM.

OF this metal only one ore has hitherto occurred; namely, *cerite*, which has been found only in Sweden.

GENUS I. OXIDES.

Sp. 1. *Cerite* †.

THIS mineral is found in Bastnas near Riddarhytta in Westmannland. Colour between carmine red, clove brown, and reddish brown. Massive and disseminated. Internal lustre scarce 1, resinous. Fracture fine splintery. Fragments indeterminate, not remarkably sharp-edged. Opaque. Streak greyish white. Powder reddish grey. Semihard. Brittle. Specific gravity 4·660. Its constituents, according to the analysis of Klaproth, are as follows:

Oxide of cerium ……	54·50
Silica ………………	34·50
Oxide of iron ………	3·50
Lime ………………	1·25
Water ………………	5·0
Loss ………………	1·25
	100·0

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* Ekeberg, Gehlen's *Jour.* v. 348.

† Klaproth, Gehlen's *Jour.* ii. 305. and Beitrage, iv. 140.

CHAP. III.

OF COMPOUND MINERALS.

THE minerals described in the last Chapter hardly ever occur insulated. They are usually united together in various groups, constituting the rocks and the soil of which the globe of the earth is composed. These groups are termed COMPOUND MINERALS. The study of them constitutes geology or geognosy; one of the most important branches of philosophy. It teaches us the structure of the globe, the relative situation of the different minerals, their connexion with each other, and the changes which they are undergoing, or have undergone. It is by numerous and skilful observations alone that any progress can be made in this difficult investigation. In Germany, mining has been long an object of greater attention than in any other country; men of science have been long employed to superintend the mines, and exact records have been kept of every thing that occurred. It is in that country, accordingly, that the greatest number of observations have been made, and the materials collected, for raising geology to the rank of a science. The difficult task has been undertaken by Werner, the celebrated Professor of Mineralogy in Freyberg, who has generalized his own ob-

Geognosy.

Generalized by Werner.

servations, and those of his predecessors, with the most exquisite skill, and constructed a theory which has excited universal attention. To the branch of science which he has thus created he has given the name of *geognosy*. Hitherto Werner's theory has been detailed only in his lectures. No intelligible account of it, so far as I know, has been published on the continent. But, in this country, we are indebted to Professor Jameson for a very full and excellent treatise on the subject, under the title of *Elements of Geognosy*. It was published in 1808, and constitutes the third volume of his *Mineralogy* *.

RESPECTING the structure of the internal parts of the earth, we have no direct means of information; but towards the superficies, this structure is laid open to our

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* To that important work I earnestly recommend the attention of every mineralogist. It contains (independent of the *theory* of Werner) a vast mass of information of the utmost consequence, with which every mineralogist ought to be acquainted. The sketch in the text, though only a very short abridgment, is as detailed as is consistent with the nature of the present work. I was indebted to Professor Jameson for the whole of the materials out of which it was formed.

There is another geological theory, in some measure the opposite of that of Werner, contrived with much ingenuity and sagacity, by a man of undoubted genius, which is well known in this country under the name of the *Huttonian theory*. It may seem at first sight singular, that I have taken no notice of this theory in the text, especially after the numerous experiments of Sir James Hall, equally unexpected and important, and the great mass of *Proofs and Illustrations* brought forward in support of it with such exquisite art and eloquence by Professor Playfair. But any examination of this theory would have been foreign to the present Chapter, as it refers not so much to the situation of the compound minerals, as to their *original formation*; a subject which must of necessity be hypothetical, and upon which therefore I do not touch.

view by ravines, rivers, mines, &c. Observations on these afford the only means of learning the structure of the earth. They constitute the foundations of geognosy, the ground work from which all the conclusions of that science are deduced. The stony masses of which the earth, as far as we know it, is composed, are sometimes *simple*, or composed of some one of the minerals described in the preceding Chapter; as, for example, *lime-stone, serpentine, quartz:* But more frequently they are compound, or composed of two or more simple minerals variously mixed and united together; as *granite*, which is composed of *quartz, felspar*, and *mica*.

Rocks.

These stony masses, or *rocks*, are numerous, and they are found in the earth laid one above another; so that a rock of one kind of stone is covered by another species of rock, and this by a third, and so on. Now in this superposition of rocks it has been observed, that their situation is not arbitrary; every one occupies a determinate place, so that they follow each other in regular order from the deepest part of the earth's crust, which has been examined, to the very surface. Thus there are two things respecting rocks which claim our attention; namely, their composition, and their relative situation. But besides the rocks which constitute almost the whole of the earth's crust, there are masses which must also be considered. These traverse the rocks in a different direction, and are known by the name of *veins*, as if the rocks had split asunder in different places from top to bottom, and the chasm had been afterwards filled up with the matter which constitutes the vein.

Follow a particular order.

Thus it appears, that when we consider compound minerals, or rocks, the subject naturally divides itself

Arrangement.

into three parts; namely, 1. The structure of rocks; 2. The situation of rocks; 3. Veins. These shall form the subject of the three following Sections.

SECT. I.

OF THE STRUCTURE OF ROCKS.

Rocks may be divided into two classes; viz.

I. Simple, or composed of one mineral substance.

II. Compound, or composed of more than one mineral substance.

Compound rocks are of two kinds; namely,

I. Cemented; composed of grains agglutinated by a cement, as *sand-stone*.

II. Aggregated; composed of parts connected together without a cement, as *granite*.

The aggregated rocks are likewise of two kinds; namely,

I. Indeterminate.

Only one instance of this kind of aggregation has hitherto occurred, namely in the *older serpentine*, where limestone and serpentine are so conjoined, that it is difficult to say which predominates.

II. Determinate.

The determinate are either, I. Single aggregated; or, II. Double aggregated.

There are four kinds of single aggregated rocks; namely,

1. Granular; composed of grains whose length, breadth, and thickness are nearly alike, and which are of contemporaneous formation. As *granite, sienite.*
2. Slaty; composed of plates laid above each other; as *mica slate.*
3. Porphyritic; composed of a compact ground, containing in it crystals which appear to have been deposited at the time the rock was formed; as *common porphyry.*
4. Amygdaloidal; composed of a compact ground, containing in it vesicles which appear to have been afterwards filled up; as *amygdaloid.*

There are five kinds of double aggregated rocks; namely,

1. Granular slaty; composed of slaty masses laid on each other. Every individual slate is composed of grains cohering together; or it is slaty in the great, and granular in the small; as *gneiss.*
2. Slaty granular; composed of large granular masses cohering together; each grain is composed of plates; or the rock is granular in the great, and slaty in the small; as *topaz rock.*
3. Granular porphyritic; granular in the small, and porphyritic in the great; as *granite, greenstone* frequently.
4. Slaty porphyritic; slaty in the small, porphyritic in the great; as *mica slate* frequently.
5. Porphyritic and amygdaloidal; a mass porphyritic and amygdaloidal at the same time; as *amygdaloid* and *basalt* frequently.

Such are the different kinds of structures of rocks hitherto observed and described. The following Table will give the reader a synoptical view of these different kinds of structure:

Table of the structure of rocks.

I. Simple rocks
II. Compound rocks
  A. Cemented
  B. Aggregated
    a. Indeterminate
    b. Determinate
      I. Single
        1. Granular
        2. Slaty
        3. Porphyritic
        4. Amygdaloidal
      II. Double
        1. Granular slaty
        2. Slaty granular
        3. Granular porphyritic
        4. Slaty porphyritic
        5. Porphyritic and amygdaloidal

SECT. II.

OF THE RELATIVE SITUATION OF ROCKS.

THE rocky masses, or rocks, hitherto observed, amount to about sixty. Of these rocks, variously placed over each other, the whole crust of the earth is composed, to the greatest depth that the industry of man has been able to penetrate. Now these rocks, with respect to each other, occupy a determinate situation, which holds invariably in every part of the earth. Thus lime-stone is nowhere found *under* granite, but always *above* it. Were we to suppose every particular rock, or *layer*, which constitutes a part of the earth's surface to be extended round the whole earth, and to be wrapped round the central nucleus, like the coat of an onion, in that case every rock would occupy a determinate place; one species would be always lowest or nearest the centre; another species would uniformly rest upon this first; a third upon the second, and so on. Now, though the rocks do not in reality extend round the earth in this uninterrupted manner; though, partly from the inequality of the nucleus on which they rest, partly from their own inequality of thickness in different places, and partly from other causes, the continuity is often interrupted; yet still we can trace enough of it to convince us that the rocks which constitute the earth's crust, considered in a great scale, are every where the same, and that they invariably occupy the same situation with respect to each other. Werner has therefore chosen this relative situation as the basis of his classification of rocks. He divides them into five Classes. The first Class consists of those rocks which, if we were to suppose each layer to be extended over the whole earth, would in that case lie *lowest*, or nearest the centre of all the rocks which we know, and be covered by all the other rocks. The second Class consists of those rocks which in that case would be immediately above the first class, and cover them. The third Class would cover the second in the same manner; the fourth the third; and the fifth would be uppermost of all, and constitute the immediate surface of the earth. The first class of rocks are covered by all the rest, but never themselves lie over any other. The others lie in order over each other. These grand classes of rocks he has denominated *formations*, and distinguished them by the following specific names :

Classes of rocks.

I. Primitive formations
II. Transition formations
III. Floetz formations
IV. Alluvial formations
V. Volcanic

The primitive formations are of course the lowest of all, and the alluvial constitute the very surface of the earth ; for the volcanic, as is obvious, are confined to particular points. Not that the primitive are always at a great depth under the surface, very often they are at the surface, or even constitute mountains. In such cases, the other classes of formations are wanting altogether. In like manner the transition, and other formations, may each in its turn occupy the surface, or constitute the mass of a mountain. In such cases, all the subsequent formations which ought to cover them are wanting in that particular spot.

Each of these grand classes of formations consists of a greater or smaller number of rocks, which occupy a determinate position with respect to each other, and which, like the great formations themselves, may often be wanting in particular places. Let us take a view of the rocks which compose all these different formations.

CLASS I.

PRIMITIVE FORMATIONS.

THE rocks which constitute the primitive formations are very numerous. They have been divided therefore into seven sets; which constitute as many primitive formations, and are distinguished each by the name of that particular rock which constitutes the greatest proportion of the formation. These seven sets of primitive formations are the following :

Principal formations.

1. Granite
2. Gneiss
3. Mica-slate
4. Clay-slate
5. Newest primitive porphyry
6. Sienite
7. Newer serpentine.

Subordinate.

The granite is the undermost, and the sienite the uppermost of the primitive formations. Granite is scarcely mixed with any other rock; but in gneiss, mica-slate, and clay-slate, there occur *beds* * of *old porphyry*,

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* When a mountain is composed of *layers* of the same kind of stone, it is said to be *stratified;* but when the layers are of *different* kinds of stone, it is said to be composed of *beds*.

primitive trap, *primitive lime-stone*, *old serpentine*, *quartz rock*. For that reason, these rocks are said to constitute formations *subordinate* to gneiss, mica-slate, and clay-slate. Gypsum occurs in beds in mica-slate, and old flint-slate occurs in the same way in clay-slate. Hence they constitute formations subordinate to mica and clay slate. Thus, besides the seven principal primitive formations, there occur seven subordinate formations, interspersed through the second, third, and fourth formations; and *topaz rock*, which lies over gneiss and under clay-slate, must be added to the list: so that the primitive formations altogether amount to fifteen.

Relative age.

If we suppose the nucleus of the earth to have been first formed, and the formations to have been afterwards deposited in succession upon this nucleus, it will follow that the lowest formation is the oldest, and that the formations are newer and newer according as they approach the surface. This supposition accounts for some of the names given to the primitive formations. That porphyry, for example, is considered as the oldest which lies lowest down in the series of formations, and those formations of porphyry which lie nearer the surface are considered as newer. Granite, of course, according to this way of speaking, is the oldest formation of all, while the alluvial are the newest of all. The following Table exhibits a synoptical view of the primitive formations:

Table of formations.

Principal.	Subordinate.
1. Granite	
	6. Older porphyry
	7. Primitive trap
2. Gneiss	8. Primitive lime-stone
3. Mica-slate	9. Older serpentine
4. Topaz rock	10. Quartz
5. Clay-slate	11. Gypsum
	12. Older flint-slate
13. Newer porphyry	
14. Sienite	
15. Newer serpentine.	

Let us consider each of them in the order of the formations.

1. *Granite.*

Composition.

Granite * is the lowest of all the formations, and the basis upon which the others rest. It is composed of *felspar*, *quartz*, and *mica*; each in a crystallized state, and cohering together without any cement. The felspar is usually the most abundant ingredient, and the mica the smallest in quantity. The colour of the quartz and mica is usually grey; but the felspar has a considerable variety of colours, occurring in different shades of white, grey, red, and green. The size of

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* Professor Jameson informs us, that the word *granite* was first used by Tournforte in his Voyage to the Levant, published in 1699. But the word occurs in the register of the Royal Society as far back as 1662; where it is mentioned that Mr Winthrop exhibited a piece of a rock of granite. See Birche's *History of the Royal Society*, i. 80.

the constituents of granite varies considerably. Sometimes the grains are very large, and sometimes they are so small that the granite has the appearance of a sandstone. Sometimes it is *porphyritic*, large crystals of felspar occurring in a basis of fine-grained granite. Sometimes this rock is distinctly stratified, but in other cases no stratification can be perceived. The unstratified or *massive* granite is frequently composed of large globular masses, each of which is composed of concentric lamellar distinct concretions. The intervals between these balls consist of a softer granite, subject to crumble down when exposed to the action of the weather.

Foreign minerals.

Besides the three constituents of which granite essentially consists, other crystallized minerals occasionally occur in it, though only in small quantities. These crystals are chiefly of *schorl ;* sometimes *garnet* and *tinstone.*

Granite very seldom contains among its strata beds of any foreign rock. Beds of felspar alone have occasionally been observed in it. It is not so rich in ores as some of the other formations. Tin and iron are the metals which are most abundant in it. Hitherto molybdena has been found chiefly in granite. It contains also silver, copper, lead, bismuth, arsenic, cobalt, tungsten, and titanium.

Newer granite.

Besides the great granite formation which has been just described, Werner has discovered a second; which is supposed to occur nearly in the same geognostic situation as porphyry and sienite. The granite veins which traverse gneiss, mica-slate, and clay-slate, belong to this formation. There are several particularities by which this newer granite may be distinguished from the other. It usually occurs in a lower level; it has commonly a deep red colour; contains garnets; and is not porphyritic.

When granite is not covered by any other formation, it forms high insulated cliffs and steep rugged rocks.

2. *Gneiss.*

Gneiss * is the formation which lies immediately over granite, and into which indeed it gradually passes. Gneiss consists of the same constituents as granite; namely, felspar, quartz, and mica: but it differs in its structure, being disposed into slates from the prevalence of the mica. The texture of the individual slates is granular. Hence the structure of gneiss is *granular slaty*. Gneiss is always distinctly stratified. It sometimes contains crystals of schorl; but they are smaller and much more uncommon than in granite. Tourmaline is more common, and so likewise is garnet. It contains in it many foreign beds, which is not the case with granite. Beds of three of the first six subordinate formations are found in it. It is, perhaps, richer in metallic ores than any other formation. Almost every metal occurs in it, either in beds or veins.

Composition.

Foreign minerals.

When gneiss is not covered by any other formation, it forms round-backed mountains, and likewise crags; but less steep and insulated than those composed of granite.

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* The word *gneiss* is of Saxon origin, and was applied by the miners to the decomposed stone which forms the walls of veins. Werner first gave it the meaning which it now bears. See Jameson's *Geognosy*, p. 113.

3. *Mica-Slate.*

The formation which lies immediately over gneiss, and into which it insensibly passes, is *mica-slate*. This rock, like the preceding, is compound, and composed essentially of quartz and mica. Like gneiss it is slaty, but it differs from that rock in containing no felspar. It is always stratified. It very frequently contains garnet crystals in considerable quantity, so as to give it a porphyritic appearance. Its structure is then slaty porphyritic. It sometimes also contains crystals of tourmaline, cyanite, and granatite. Felspar likewise occurs in it occasionally; not, however, as a constituent, but in kidneyform and irregular masses. Like gneiss, it contains many foreign beds (older porphyry, primitive trap, primitive lime-stone, older serpentine, and gypsum, occur in it). It is rich in ores; containing beds of magnetic iron-stone, pyrites, galena, copper pyrites (containing gold), blende, cinnabar, cobalt glance, magnetic pyrites, and sometimes even native gold. It abounds also in metalliferous veins.

Foreign minerals.

4. *Clay-Slate.*

Mica-slate gradually passes into clay-slate, the formation immediately over it. Clay-slate consists essentially of the mineral described in the preceding Chapter under that name. This rock is always slaty and always stratified. When it approaches, mica-slate, grains of quartz, and also of mica, may be distinguished in it. Occasionally also it contains crystals of felspar, schorl, tourmaline, garnet, and hornblende.

Comprehends a variety of slates.

Under the name of *clay-slate formation* is included not only clay-slate, strictly so called, but likewise *chlo-*

rite-slate, *talc-slate*, *whet-slate*, *drawing-slate*, and *alum-slate*; all of which occur along with pure clay-slate, are similarly stratified, and gradually pass into it and into each other, and therefore are considered as only constituting a part of the same formation: But these substances affect a particular order. The following Table exhibits that order, beginning with the lowest or oldest, as it is called, and terminating with the uppermost or newest:

Their relative position.

1. Light yellowish grey clay-slate
2. Dark grey clay-slate
3. Green clay-slate
4. Chlorite slate and potstone
5. Talc-slate
6. Whet-slate
7. Bluish grey clay-slate
8. Red clay-slate
9. Drawing-slate
10. Alum-slate.

Foreign minerals.

Besides these different beds, which are considered as constituting the clay-slate formation, it contains also beds of all the eight subordinate formations. It contains also a considerable number of metallic ores in beds; as iron pyrites, copper pyrites, arsenic pyrites, cobalt, galena, &c. It contains also a variety of mineral veins.

HAVING now described the four first primitive formations, let us proceed to the subordinate formations; taking topaz rock along with them, on account of its rarity. These are the older porphyry, primitive trap, primitive lime-stone, older serpentine, quartz, topaz rock, gypsum, and primitive flint-slate.

5. *Older Porphyry.*

By porphyry, as defined by Werner, is to be understood a rock consisting of a basis or ground of some compact mineral, and in this ground are interspersed crystals of some other mineral. The ground or basis varies in different porphyries. Sometimes it is clay-stone, sometimes pitch-stone, &c.; and the porphyry is named from this basis. The following are the species of porphyry that have been described:

Species.

1. Clay porphyry
2. Horn-stone porphyry
3. Felspar porphyry
4. Pitch-stone porphry
5. Sienite porphyry
6. Obsidian porphyry
7. Pearl-stone porphyry.

The crystals interspersed through the different bases are commonly felspar, sometimes quartz, and sometimes hornblende and mica; but the two last are uncommon, especially the mica.

Two formations of porphyry.

There are two very different formations of porphyry: the first is found in beds in gneiss, mica-slate, and clay-slate; whereas the second always lies over all these formations. Hence the first is distinguished by the name of *older*, and the second is called *newer porphyry*. It is the first of these that we are to consider at present.

Older.

The basis of the older porphyry is usually a species of horn-stone, and sometimes felspar; and the crystals which occur in it are felspar and quartz. Hence the older porphyry consists chiefly of *horn-stone porphyry*, and *felspar porphyry*. When not covered by other formations it sometimes forms single rocks, but never large mountains.

6. *Primitive Trap.*

Definition.

The word *trap* is Swedish, and signifies a *stair*. It was applied by the Swedish mineralogists to certain rocks, whose strata when exposed, from the one jutting out under the other, gave an appearance somewhat like a stair. The term was adopted by other nations, and was applied indiscriminately to a great variety of rocks, which bore a certain resemblance to each other. This generalization introduced much confusion into the subject, which was first cleared up by Werner and his disciples. Under the term *traps* Werner comprehends certain series of rocks, distinguished chiefly by the hornblende, which they all contain. In the most ancient, the hornblende is almost pure: this purity gradually diminishes, and in the most recent traps the hornblende degenerates to a kind of indurated clay. There are, then, three formations of trap: 1. Primitive trap; 2. Transition trap; 3. Floetz trap. The first only occupies our attention at present.

Three formations.

Primitive.

The primitive trap formation contains a considerable number of rocks; which, occurring in different parts of the earth in similar situations, and as it were substituted for each other, are considered altogether as constituting only one formation. The following Table exhibits a list of the rocks belonging to this formation:

Rocks belonging to it.

I. Hornblende
    1. Granular or common hornblende
    2. Hornblende slate

- II. Hornblende and felspar united
  - i. Granular
    - 1. Common green-stone
    - 2. Porphyritic green-stone
    - 3. Green-stone porphyry
    - 4. Green porphyry
  - ii. Slaty
    - 1. Green-stone slate
- III. Hornblende and mica united
  - 1. Porphyritic trap.

The first two of these rocks consists essentially of the minerals described in the last chapter under the names of common *hornblende* and *hornblende slate*. The latter sometimes passes into fine slaty gneiss and into chlorite slate.

Common green-stone is composed of hornblende and felspar, both in the state of grains or small crystals, and the hornblende usually constitutes by far the greatest proportion of the mass. The felspar is almost always tinged green from the hornblende. This rock sometimes contains a little mica; sometimes it is intersected by small veins of quartz and actinolite; and sometimes also, though less frequently, of felspar and calcareous spar.

Porphyritic green-stone, like the preceding rock, is a compound of granular hornblende and felspar; but it contains likewise large crystals of felspar and quartz, interspersed through the green-stone ground.

Green-stone porphyry (black porphyry of the antiquary) is a rock consisting of granular green-stone, so small-grained that at first sight it has the appearance of being a simple stone; containing in it large crystals of felspar, coloured green from hornblende.

Green porphyry (the *verde antico serpentine*) is a rock which has for its ground a mixture of hornblende and felspar, so intimate that the two ingredients cannot be distinguished by the naked eye, and having a blackish green or pistachio green colour. This trap contains greenish coloured felspar crystals, often cruciform.

Green-stone slate is a rock composed of hornblende and felspar, and sometimes a little mica, and having a slaty texture. It is very hard; but, like the other species of green-stone, soon withers when exposed to the air.

Porphyritic trap is a rock composed of an intimate mixture of hornblende and felspar, containing in it large plates of mica, which give it a porphyritic appearance.

All the rocks of the primitive trap formation are characterized by containing a mixture of iron pyrites. Their stratification is indistinct; and, indeed, if we except green-stone slate and hornblende slate, usually not perceptible. When primitive trap is not covered by any other formation, it constitutes considerable hills and cliffs. It abounds in ores, especially green-stone slate.

7. *Primitive Lime-Stone.*

Lime-stone occurs in all the four grand classes of formations, but it assumes a peculiar and characteristic appearance in each. In the primitive it is distinctly crystalline and transparent. The crystalline texture gradually becomes less and less distinct, as the formations advance, till at last the lime-stone assumes the appearance of an earthy deposite.

Primitive lime-stone occurs usually in beds, and seldom forms entire mountains. Its colour is usually white, sometimes it is grey, but very seldom assumes any other colour. It is the species of lime-stone described in the preceding chapter under the name of *granular foliated*. It sometimes contains in it quartz, mica, hornblende, actinolite, garnet, tremolite, talc, clay-slate, serpentine, asbestus, blende, galena, common and magnetic pyrites, and magnetic iron-stone. The ores are usually found at the lower part of the beds of lime-stone. It is sometimes stratified, and sometimes not. When not covered by any other formation, it forms steep bare rocks; and when it cccurs in considerable quantities, often contains caverns.

Foreign minerals.

8. *Older Serpentine.*

The serpentine formation consists essentially of the mineral described under that name in the preceding Chapter. Two subspecies were there described; namely, the *common* and *precious* serpentine. The latter (at least chiefly) constitutes the formation at present to be described. It occurs, like the other subordinate primitive formations, in beds in gneiss, mica, and clay-slate, and alternates with lime-stone. It is seldom stratified. It contains in it galena, and auriferous arsenic pyrites.

9. *Quartz.*

Quartz occurs in beds, and in no great quantity. It is usually granular and of a white colour; sometimes it contains a mixture of mica, which gives it a slaty texture. It is very often unstratified; but as it abounds in rents, these have often been mistaken for strata.

10. *Topaz Rock.*

The rock which constitutes this formation is very rare, having been observed only in Saxony, where it constitutes a mountain. There it rests on gneiss, and is covered by clay-slate. It is composed of three ingredients; namely, *fine granular quartz*, *schorl*, in thin prismatic distinct concretions, and *topaz* almost massive. These are arranged in thin layers, and these again into roundish and granular distinct concretions, so that the rock is *slaty granular*. The intervals between these concretions are filled up with a yellowish or greenish coloured lithomarge.

11. *Gypsum.*

Gypsum was formerly believed to be peculiar to the floetz formations; but an immense bed of it has lately been discovered in Switzerland in mica-slate. This primitive gypsum is characterised by containing mica and clay slate *.

12. *Primitive Flint-Slate.*

This rock consists essentially of the mineral described in the last Chapter, under the name of *flint-slate*. It is often traversed by veins of quartz. There are two formations of it; namely, the *primitive*, which occurs in beds in clay-slate, and another which belongs to the transition formations.

Having now described the eight formations which are subordinate to gneiss, mica, and clay-slates, let us proceed to the remaining primitive formations, which

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* It was first observed by Freisleben at the bottom of St Gothard. D'Aubuisson observed a bed of it in mica-slate in a mountain between the valley of Cogne and Fenis in the High Alps. *Jour. de Phys.* lxv. 402.

always cover clay-slate, and are therefore considered as newer than it. These are the newer primitive porphyry, sienite, and the newer serpentine.

13. *Newer Porphyry.*

To this formation belong the following species of porphyry; namely, *clay porphyry*, *pitch-stone porphyry*, *obsidian porphyry*, *pearl-stone porphyry*, and sometimes *felspar porphyry*. Clay porphyry is by far the most common. To this formation also belongs *clay-stone*, a mineral described in the preceding Chapter. It constitutes the basis of clay porphyry, and frequently occurs without any crystals of felspar or quartz. To it we must also refer a kind of breccia porphyry, composed chiefly of fragments of hornstone porphyry and felspar porphyry.

In the rocks belonging to this formation, it is common to find round masses of a harder and more flinty stone than the mass of the rock itself. Thus in clay porphyry we find masses of horn-stone porphyry, containing in their centre a kernel of chalcedony; in pitchstone porphyry we find masses of conchoidal hornstone, with a quartz kernel in the centre. Agate, chalcedony, heliotrope, amethyst, and quartz, often occur either in plates, thin beds, veins, or irregular masses; sometimes also the precious opal is found in this formation occupying clefts. It contains also a variety of ores, as of gold, silver, lead, iron, tin, manganese, &c; but hitherto they have been discovered only in veins, and never in beds.

This formation lies over all the preceding, and consists of beds more irregular, and more interrupted. It extends very widely. Hitherto it has scarcely been discovered stratified. When it composes hills, they are often split into columns like those of basalt.

14. *Sienite.*

This rock occurs usually along with porphyry; and when they are both together, the sienite generally forms the uppermost part of the hill.

Sienite is a rock composed essentially of felspar and hornblende, the same constituents which form greenstone; but in sienite the felspar is the prevailing ingredient, whereas in greenstone it is the hornblende. In sienite the felspar is usually red, and very seldom has a tinge of green, whereas in greenstone the felspar is never red, but almost always greenish white. The structure of sienite is granular, and the grains vary greatly in size: sometimes small-grained sienite contains in it large crystals of felspar; it is then called *porphyritic sienite.* When the two ingredients that constitute sienite are so small, and so intimately mixed, that they cannot be distingnished by the naked eye, and when such a rock contains crystals of felspar and quartz, it is denominated *sienite porphyry.*

Sienite, like porphyry, contains few foreign beds; but it is rich in ores, containing gold, silver, iron, tin, copper, lead, &c. always however in veins.

The rocks of sienite are often divided into columns. Like the newer porphyry it often occurs in round masses.

15. *Newer Serpentine.*

This formation consists of the rock composed essentially of the mineral called common serpentine. It bears a striking resemblance to the newer porphyry formation, and occurs in similar situations; but whether it covers it, is covered by it, or comes in place of it, has not hitherto been ascertained in a satisfactory manner. It sometimes contains steatite, asbestus, talc, meerschaum, native magnesia, pyrop, and schillerstone. It is seldom or never stratified, and except magnetic iron-stone contains scarcely any ore.

Remarks.

SUCH is a sketch of the rocks constituting the primitive formations. It deserves attention, 1. That the rocks constituting them are all chemical combinations, and generally crystallized; the crystallized appearance being most striking in the oldest, and gradually becoming less perfect in the newer formations; 2. That they contain no petrefactions; 3. That the oldest formations contain no carbonaceous matter, and that it occurs only very sparingly in the primitive formations. Slaty glance coal and graphite occur in them. 4. That when we compare together the height of the different formations, where each individual is not covered by any succeeding one, we find that *granite* stands *highest* of all; that the level of the *gneiss* is a little *lower;* that of the *mica slate* still *lower;* and that of the *clay-slate lowest* of all. So that there is a regular sinking of the level from granite to clay-slate; but the newer porphyry and sienite are laid over the tops of the preceding, as if these two formations had been deposited long after the formation of the rest. Nay, there is often interposed between the porphyry and these formations a bed of breccia, composed of fragments of the anterior formation. 5. That almost all the rocks which contain magnesia are confined to the clay-slate formation.

CLASS II.

TRANSITION FORMATIONS.

HAVING described the primitive formations, let us now proceed to the second great Class, the *transition*, which lie immediately over them. These are by no means so numerous, since they consist only of four sets; namely,

1. Grey wacke
2. Transition lime-stone
3. Transition trap
4. Transition flint-slate

They all alternate with each other, sometimes one, sometimes another being undermost, except one bed of transition lime-stone, which seems always to rest upon the primitive formations, and may therefore be considered as the oldest of the transition formations.

Why called *transition*.

It is in the transition rocks that petrefactions first make their appearance; and it deserves particular attention that they always consist of species of corals and zoophites, which do not at present exist, and which therefore we must suppose extinct. The vegetable petrefactions are likewise the lowest in that kingdom, such as ferns, &c. This remarkable circumstance has induced Werner to conclude, that the transition rocks were formed after the earth contained organic beings. Hence the name *transition*, which he has imposed, as if they had been formed when the earth was passing from an uninhabited to an inhabited state. The date of their formation is conceived to be very remote, since the petrefactions which they contain are the remains of animal and vegetable species now extinct. It is in the transition rocks, too, that carbonaceous matter makes its first appearance in any notable quantity.

1. *Greywacke.*

This formation consists of two different rocks, which usually alternate with each other, and pass into each other. These are *greywacke*, and *greywacke-slate.* The first characterizes the formation.

Greywacke is a rock composed of pieces of quartz, flint-slate, felspar, and clay-slate, cemented together by a basis of clay-slate. The pieces are sometimes as large as a hen's egg; sometimes so small that they cannot be perceived by the naked eye. The clay-slate basis likewise varies in quantity considerably. It often contains soft plates of mica, and quartz veins are very common in it; sometimes it is so hard that it appears indurated by some siliceous cement. The texture of greywacke becomes gradually finer and finer grained, till at last it can no longer be perceived, and a slaty structure succeeds. It then passes into greywacke-slate.

Greywacke-slate is nothing else than a variety of *clay-slate;* but it may be distinguished from primitive slate by different circumstances. Its colour is usually ash or smoke-grey, seldom showing that greenish or light yellowish grey colour which is so common in primitive slate. It does not show the silvery uninterrupted lustre of primitive slate, but is rather glimmering, from interspersed scales of mica. It contains no beds of quartz, but very often veins of that mineral. It contains no crystals of felspar, schorl, tourmaline, garnet, or hornblende; nor beds of garnet, chlorite slate, talc, or magnetic iron-stone. It contains petrefactions.

Foreign minerals.

The greywacke rocks are stratified. When not covered by any other formation, they form round-backed hills, usually insulated at top and intersected by deep valleys. It contains immense beds of transition lime-stone, trap, and flint-slate. It is rich in ores both in beds and veins, and the veins are often of an uncommonly large size.

2. *Transition Lime-Stone.*

This, like primitive lime-stone, is a simple rock; but it approaches more to compact, and is less transparent than the primitive. It contains often veins of calcareous spar, and exhibits a variety of colours, which gives it a *marbled* appearance. It contains marine petrefactions of corals and zoophites, which no longer exist, and which do not occur in the subsequent lime-stone formations. These petrefactions increase in quantity as the beds of transition lime-stone advance farther and farther in their position from the primitive formations. It is often mixed with greywacke-slate, which gives it a slaty texture. It occurs in beds of greater and smaller size, and often forms whole mountains. It contains no foreign beds except of transition trap. It is scarcely stratified. It is rich in ores.

2. *Transition Traps.*

This formation, as the name imports, consists of rocks distinguished by the great proportion of hornblende which they contain. It comprehends four species of rocks; namely,

Rocks included.

1. Transition green-stone
2. Amygdaloid
3. Porphyritic transition trap
4. Globular trap (kugel fels)

Transition green-stone is a rock composed of fine granular hornblende and felspar intimately mixed together, and not so distinctly crystallized as in primitive green-stone. Sometimes the mixture is so intimate, that the two minerals cannot be distinguished. In that state it often becomes loose in its texture, and approaches *wacke* and *basalt*. In this last case it often contains vesicles. When these are filled up with other minerals, the rock passes into *amygdaloid*.

Amygdaloid is nothing more than this last state of green-stone. The vesicles are filled up with calcareous spar, chalcedony, quartz, jasper agate, green earth, amethyst, &c. either completely or partially.

Sometimes the transition green-stone, in this softened state, contains crystals of felspar coloured green by the hornblende. It then constitutes *porphyritic transition trap*.

Globular trap is a fine granular hornblende rock of a loose texture, and tending very strongly to clay; of a liver brown colour, and containing in it globular masses composed of concentric lamellar concretions, and containing a hard kernel.

The transition trap rocks are only doubtfully stratified. They alternate with the other transition formations in beds, and sometimes compose whole mountains. Common and lenticular clay iron-stone occurs in it in beds.

4. *Transition Flint-Slate.*

This formation consists essentially of common flint-slate and Lydian stone, which pass into each other. It is a simple stone, but is characterised by containing many veins of quartz. It is not stratified. When it constitutes rocks they are usually steep, and appear very much lacerated and worn down by the weather. This is occasioned by the numerous rents which this species of rock contains.

To this formation seems to belong ribbon jasper, which sometimes constitutes whole rocks. It may possibly occur also in some of the subsequent formations.

To these formations may be added transition gypsum, which Von Buch discovered, constituting a bed in greywacke slate, at Leogang in Salzburg *.

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* Jameson's *Geognosy*, p. 152.

CLASS III.

FLOETZ FORMATIONS.

The next grand Class of formations have received the name of *floetz*, because they lie usually in beds much more nearly horizontal than the preceding. When not covered by a succeeding formation, they form hills which do not rise to the same height as the primitive or transition. They contain abundance of petrefactions; and these much more various in their nature than those which occur in the transition formations, consisting of shells, fish, plants, &c. indicating that they were formed at a period when organized beings abounded.

The floetz formations lie immediately over the transition. They comprehend a great number of individual formations, each of which affects a particular situation. The following Table exhibits a view of these different formations in the order of their position, as far as is known:

Table of the formations.

1. Old red sand-stone
2. First floetz lime-stone
3. First floetz gypsum with rock salt
4. Variegated sand-stone
5. Second floetz gypsum
6. Second floetz or shell lime-stone

* * *

7. Third sand-stone or free-stone

* * *

8. Chalk

* * *

9. Independent coal
10. Floetz trap.

The position of the two formations separated from the rest, and from each other, by asterisks, has not been ascertained in a satisfactory manner. The last formation, the floetz trap, lies over the rest, pretty much as the newer porphyry and sienite do over the older primitive formations.

1. *Old Red Sand-Stone.*

This formation lies immediately over the transition, or, where they are wanting, over the primitive rocks. Hence it is considered as the oldest of the floetz formations.

Sand-stone is composed of grains of quartz, or some other siliceous stone, cemented together by some basis, and can only be considered as a mechanical mixture. The cement is sometimes clay, sometimes quartz, lime, marl, &c. and the sand-stone is named in consequence, argillaceous, siliceous, calcareous, marly, &c. This cement varies much in quantity, but never predominates; sometimes it is too small in quantity to be perceived. The size of the grains is no less subject to variation; when they are large the rock is sometimes called *pudding-stone*.

The old red sand-stone has usually a red colour. Its grains are large. They consist of quartz, flint-slate, &c. cemented by iron-shot clay. It is distinctly stratified, and contains few ores. Cobalt, however, occurs in it; and it is often impregnated with copper, from the formation which lies over it.

2. *First Floetz Lime-Stone.*

Floetz limestone is usually of a grey colour; its fracture is compact; it has no lustre, and is only translucent on the edges. Sometimes, indeed, thin beds of granular foliated lime-stone occur in it; but they contain petrefactions, which distinguish them from primitive lime-stone. Floetz lime-stone is well characterized by the masses of hornstone and flint which it contains.

Foreign minerals.

The first floetz lime-stone formation lies over the old red sand-stone, and is well characterized by a bed of bituminous marl-slate, containing copper, which is peculiar to it. This bed is always situated lowest, and therefore immediately contiguous to the sand-stone. It contains but few petrefactions; and when they occur they are in the undermost strata, and in the bituminous marl bed. They consist chiefly of fish. Various beds of marl occur in this formation, and likewise a species of vesicular lime-stone, known in Germany by the name of *rauch wacke.*

3. *First Floetz Gypsum.*

Gypsum, in general, may be considered as a simple rock; sometimes, however, it contains crystals of boracite, arragonite, and quartz. Sulphur is likewise found in it, both disseminated and in compact masses. There are two formations of it.

The first floetz gypsum lies immediately over the first floetz lime-stone. I consists chiefly of foliated and compact gypsum, together with a good deal of selenite. It is in this formation that swine-stone occurs, either in beds or mixed with the gypsum. Rock salt also belongs to it, and appears to lie over it in short thick beds, being usually mixed with a species of saline clay. Hence the saline springs, which obviously originate from rock salt, are likewise peculiar to this formation.

Rock salt and salt springs.

4. *Variegated Sand-Stone.*

This formation lies immediately over the preceding. The rock which composes it consists of a fine granular argillaceous sand-stone, usually of a green, brown, red, and white colour. Several of these colours alternate in stripes, which gives the stone a variegated appearance. Hence the name. It often contains masses of a fat clay, of a greenish, reddish, or yellowish colour.

Foreign minerals.

This formation is characterized by two species of rocks, which occur in it in beds. These are, 1. The subspecies of lime-stone described in the last Chapter under the name of *roe-stone ;* and, 2. *Sand-stone slate.* The first is almost peculiar to this formation ; but the second is found also, though in small quantity, in the *old red sand-stone.* It consists chiefly of fine micaceous scales, forming a slaty texture, and having generally thin layers of fine granular sand-stone interposed between them.

5. *Second Floetz Gypsum.*

This formation lies over the preceding in beds, and is sometimes, to a certain degree, mixed with it. It contains foliated gypsum, but scarcely any selenite, and no swine-stone ; and is characterized by the fibrous gypsum, of which it is in a great measure composed. It is of no great extent; and, like the first floetz gypsum, is destitute of petrefactions.

6. *Second Floetz Lime-Stone,* or *Shell Lime-Stone.*

This formation is separated from the first floetz limestone by the beds of older gypsum, of variegated sandstone, and of second gypsum; which constitute the third, fourth, and fifth formations. It is characterized by the vast number of shells which it contains in the state of petrefactions. It contains little marl; and only individual beds or seams of coal occur in it, so small as not to be worth working. In many places flint and hornstone are found in it; sometimes in small beds, sometimes in plates, and sometimes massive or in roundish pieces. Particles of galena are likewise found scattered through it.

7. *Third Sand-Stone,* or *Free-Stone.*

Though the relative position of this formation has not been well ascertained, yet it is known to cover all the preceding, and therefore to be much newer than either the first or second sand-stone formations. It consists mostly of a sand-stone of a white colour, well adapted for building. It contains traces of coal, but no sand-stone, slate, nor roe-stone; and gypsum never occurs either immediately over or under it. It is usually stratified, and contains natural rents or seams, which cross each other at right angles; the one parallel to the stratification, the other perpendicular to it, so that it can be easily quarried into large square blocks. This indeed is a character that in some measure applies to all the sand-stones. When not covered by any other formation, it forms beautiful hills and romantic valleys.

8. *Chalk.*

Chalk is one of the newest floetz rocks. It is always near the sea-coast. It contains numerous beds of nodular flint, often full of vesicles. Various petrefactions of echinites, belemnites, &c. occur in it. It is indistinctly stratified, and forms beautiful round knolls and hills of very small height. Pyrites is sometimes found in it, but scarcely any other metallic ore.

9. *Independent Coal Formation.*

This formation is deposited in detached patches, usually in valleys over the preceding floetz rocks, or over the transition formation when the floetz rocks are wanting. These patches, in general, have no connexion with each other. Hence the epithet *independent*, by which the formation is distinguished: but they are found in considerable quantities in the most distant parts of the earth, Europe, America, New Holland, and always similarly situated with respect to the other formations. Coal occurs in it in great abundance; though in the preceding formations it is very scarce, and indeed is only found in thin individual beds. Hence it is considered as characteristic of this formation. The rocks of which (not reckoning the coal) this formation is composed are the following:

Rocks belonging to it.

Sand-stone
Coarse conglomerate
Slate-clay
Bituminous shale
Indurated clay
Lime-stone
Marl
Clay iron-stone
Porphyritic stone
Green-stone.

Layers of these rocks alternate a great many times with each other, and in them the coal occurs in numerous beds, varying extremely in thickness. The subspecies of coal which occur in this formation are *coarse coal*, *foliated coal*, *cannel-coal*, *slate-coal*, and a little *pitch-coal*. Professor Jameson has likewise discovered glance coal in this formation.

Includes several subordinate formations.

All the different rocks of which this formation is composed seldom or never occur together. Hence it is presumed, that there are several subordinate formations belonging to the independent coal, which occupy determinate situations with respect to each other. Three such formations have been characterized. The oldest or lowest is composed of beds of *indurated clay*, *lime stone*, *marl*, *porphyritic stone*, *slate-clay*, *bituminous shale*, *green-stone*, and *soft sand stone*, and is characterized by containing in it some metallic ores. These are ores of *copper*, *iron*, *lead*, and perhaps also *mercury*. The second is composed of beds of *indurated clay*, *marl*, *lime-stone*, and *porphyritic stone*. It contains some pyrites, but no other ore. The third, or newest, is composed of *soft sand-stone*, *conglomerate*, and *slate-clay*, and contains no ore.

The *sand-stone* of this formation consists usually of grains of quartz, differing in size, and cemented by a calcareous or argillaceous, and sometimes even a siliceous basis. Its colour is various, though most commonly grey, and it often contains very thin seams of coal interspersed through it. It is often employed in building.

The *conglomerate* consists of fragments of lime-stone, quartz, greywacke, &c. cemented together by a basis of clay.

The *slate-clay, bituminous shale,* and *indurated clay,* are the minerals described in the last Chapter under these names.

The *lime-stone* belongs to the *compact* subspecies, has a splintery fracture, and is scarcely translucent on the edges.

The *marl* and *clay iron-stone* are the minerals described in the preceding Chapter under these names. The *green stone,* which was first discovered in this formation by Professor Jameson, belongs to the species which occurs in the floetz trap rocks, to be described immediately. The *porphyritic stone,* I presume, consists of a clay basis, containing crystals of felspar.

The rocks belonging to this formation are very distinctly stratified. Abundance of petrefactions occur in it, especially in the sand-stone and bituminous shale. They are chiefly of vegetables ; ferns, reeds, &c. are the most common. Those in the sand-stone are usually rather casts of vegetables than real petrefactions. They seem often to resemble palms, &c. ; but none of them have been distinctly referred to any vegetable species at present existing.

10. *Floetz Trap.*

The rocks of this formation are very remarkable. They cover the other floetz rocks, precisely as the newer porphyry and sienite do the primitive. The level of the uncovered floetz formations becomes gradually lower, in the order in which they have been described ; but that of the floetz trap is high, as it covers them all, and often forms the summit of hills whose lower part consists of older formations. The rocks belonging to the floetz trap formations are of two kinds ;

namely, those which are peculiar to it, and those which occur also in other formations. The following are the rocks peculiar to this formation:

Rocks peculiar to this formation.

- Wacke
- Iron-clay
- Basalt
- Pitch-stone
- Green-stone
- Porphyry slate
- Grey-stone
- Amygdaloid
- Trap tuff

Basalt claims the first place, as it characterizes the floetz formation. It consists essentially of the mineral described in the last Chapter, under the name of *basalt*, for a basis, containing crystals of basaltic hornblende, augite, olivine, and iron-sand, which give it a porphyritic structure. It contains also vesicles, which are filled with zeolite, calcareous spar, lithomarge, &c. The vesicles are sometimes filled with water. Sometimes it passes into wacke; sometimes into grey-stone; and sometimes, though rarely, into porphyry slate.

Wacke is sometimes the simple mineral described under that name in the preceding Chapter. Sometimes it contains basaltic hornblende and mica, which give it a porphyritic appearance; sometimes it is spotted, from crystals which it contains. It passes sometimes into clay; sometimes into basalt. The *iron-clay* likewise has been described in the preceding Chapter.

Pitch-stone was first observed in this formation by Professor Jameson. It is distinguished from that which occurs in the older rocks by the following circumstances. Its colours are usually black or green; it is composed of lamellar distinct concretions, and it contains crystals of glassy felspar, or *meionite* as it is called.

Porphyry slate is much less common than basalt; but where it does occur it usually forms considerable hills. This rock is slaty in the large, compact and splintery in the small. The basis of it consists of clink-stone; the crystals which it contains are of felspar and hornblende. It contains also zeolite, iron-sand, and some minerals not yet described.

Grey-stone is still less common than porphyry slate. It appears to consist of an intimate mixture of much white felspar and a little black hornblende. This basis contains augite and olivine.

Floetz green-stone is an intimate mixture of grains of felspar and hornblende. It is distinguished from primitive and transition green-stone by the more intimate mixture and less crystallized appearance of the constituents. It passes into basalt.

Amygdaloid has for its basis sometimes *wacke*; sometimes a fine granular green-stone, frequently already somewhat decomposed. The vesicles which it contains are filled with green earth, lithomarge, steatite, &c. Sometimes they remain empty; sometimes this basis contains crystals of hornblende, &c. which gives the rock both a porphyritic and amygdaloidal structure.

Trap tuff consists of fragments of floetz trap and other rocks, cemented by a basis of alluvial clay.

The minerals which this formation contains, in common with others, are not so numerous as the preceding. They are the following:

Other minerals contained.

Sand
Quartzy sand-stone
Clay
Lime-stone
Coal.

The grains of sand are of all degrees of magnitude. The clay sometimes contains *schaum earth.* The coal consists chiefly of the following subspecies: *Common brown coal*, *bituminous wood*, and *pitch-coal.* Sometimes, though seldom, *glance coal* and *columnar coal* occur in this formation.

The lowest bed of the floetz trap formation consists of sand, which becomes gradually finer and finer as we approach the upper part of the bed; at last it becomes clayey, and gradually passes into indurated clay. Over this lies a bed of wacke, into which the clay gradually passes. The wacke, in its turn, passes into basalt; and the basalt into green-stone, grey-stone, or porphyry slate, which constitute the uppermost part of the formation: so that the lowest part of this formation consists entirely of a mechanical deposite, while the uppermost part has the appearance of a chemical compound. Instead of the sand, we sometimes find the quartzy sand-stone, as if the sand had been united together by a siliceous cement.

When coal occurs in this formation it commonly lies under the basalt. In these cases, beds of sand, clay, wacke, basalt, &c. are found in several repeated series.

All the rocks of this formation seldom or never occur together; sometimes one, sometimes more, are wanting. They are commonly horizontally stratified, and form conical, insulated rocks, often flat at the top. This formation extends over the whole earth, but the beds are broken and interrupted, so as to cap detached mountains, or fill up hollows, but all similarly situated with regard to each other. It is the newest of the floetz formations, as it covers not only the older, but likewise even the newest floetz formations.

Formations near Paris.

Besides these formations, there appear to be several others not yet described. How far these are universal or limited to particular spots has not yet been decided. Thus in the environs of Paris, the lowest rock known consists of chalk in very thick beds. Over the chalk lie about 11 beds of various substances, nearly in the same order and thickness in all the hills in the neighbourhood. These beds are obviously newer than the chalk; and they differ in their nature from all the floetz formations above described. An excellent account of these beds has lately been published by different mineralogists in Paris, especially De la Metherie, and Cuvier, and Brogniart. The following are these beds arranged according to their position, beginning with the lowest in the order, and terminating with that at the surface of the earth.

1. Clay
2. Limestone
3. Plaster, or a mixture of gypsum and limestone
4. Marl and adhesive slate
5. Plaster
6. Marl and adhesive slate
7. Plaster
8. Marl and adhesive slate
9. Clay containing sulphate of strontian in nodules
10. Marl
11. Sand.

1. The bed of clay is about 30 feet thick; but it varies in thickness in different places. It contains very thin beds of sand, and a kind of bituminous matter is found in it which burns when heated, and emits a smell like coal.

2. The lime-stone differs in its appearance, but the greatest part of it is a species of roe-stone full of small shells. It is the stone employed for building in Paris. At first it is very soft, but it hardens by exposure to the air. It is subject to moulder down, and hence the decay observable in several of the public buildings of that capital. A stone nearly similar occurs in the neighbourhood of Bath, and is there employed as a building stone. It is not improbable, from this circumstance, that formations similar to those at Paris occur near Bath.

3. Over the lime-stone lies a bed of plaster about 16 feet thick, called by the workmen the *low mass*. It is mixed here and there with marl and adhesive slate. It contains also thin beds of selenite.

4. Over the *low mass* lies a bed of marl and adhesive slate about 16 feet thick.

5. Over this lies the second bed of plaster, about 15 feet thick, called the *middle mass*, and divided into several layers; some of these consist of ordinary plaster, others of *selenite*, called *grignards* by the workmen, and rejected by them.

6. Over the *middle mass* lies a bed of adhesive slate and marl, about 20 feet thick. This bed in Montmartre contains a thin bed of variegated clay, a kind of fuller's earth. Instead of this, *menilite* occurs in Meneil-Montant. It contains rifts, often filled with lenticular selenite.

7. Over the preceding lies a bed of plaster about 50 feet thick, called by the workmen the *high mass*. It is divided into a number of layers. This bed at Menil-Montant is divided into irregular columns, similar to those so common in basaltic and green-stone

mountains. It contains a number of siliceous nodules like agates, often hollow within and filled with plaster.

8. Over the *high mass* lies a bed of marl and adhesive slate, about 70 feet thick, and very distinctly stratified. It contains vegetable petrefactions.

9. Over this lies a bed of greenish coloured clay about 18 feet thick. It contains very impure sulphate of strontian in irregular nodules, which form thin beds like flint in chalk. It contains also regular crystals of selenite.

10. Over this lies a bed of marl about 18 feet thick, regularly stratified, and in the lower part of which occur a great variety of common oyster shells.

11. The uppermost bed of all, which crowns the hills in the neighbourhood of Paris, consists of fine sand, containing in it abundance of sea shells. Sometimes this sand is agglutinated, constituting a kind of sand stone. Sometimes it becomes hard enough to be used as a mill-stone. Sometimes it contains masses of a kind of clay iron-stone. It contains abundance of mica. It is about 55 feet thick.

It is chiefly in the beds of plaster that the great number of fossil bones of land animals have been found, for the description of which we are chiefly indebted to Cuvier *.

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* See *Jour. de Phys.* lxvi. 309.

CLASS IV.

ALLUVIAL FORMATIONS.

The alluvial formations constitute the great mass of the earth's surface. They have been formed by the gradual action of rain and river water upon the other formations, and may be considered as very recent formations, or rather as deposites, the formation of which is still constantly going on. They may be divided into two kinds: namely, those deposited in the valleys of mountainous districts, or upon the elevated plains which often occur in mountains; and those deposited upon flat land.

Of two kinds.

The first kind consist of sand, gravel, &c. which constituted the more solid parts of the neighbouring mountains, and which remained when the less solid parts were washed away. They sometimes contain ores (particularly gold and tin) which existed in the neighbouring mountains. Sometimes the alluvial soil is washed, in order to separate these ores. On mountain plains there occur also beds of loam.

The second kind of alluvial deposite, or that which occupies the flat land, consists of loam, clay, sand, turf, and calctuff. Here also occur earth and brown coal (in this mineral amber is found), wood coal, bituminous wood, and bog iron ore. The sand contains some metals, among others gold. The calctuff is a chemical deposite and extends widely. It contains plants, roots, moss, bones, &c. which it has encrusted. The clay and sand often contain petrified wood, and likewise skeletons of quadrupeds.

CLASS V.

VOLCANIC FORMATIONS.

THE volcanic formations are of two kinds; namely, the *pseudo-volcanic* and the *true volcanic*.

Pseudo-volcanic.

The pseudo-volcanic consist of minerals altered in consequence of the burning of beds of coal situated in their neighbourhood. *Porcelain jasper*, *earth slag*, *burnt clay*, *columnar clay-iron stone*, and perhaps also *polishing slate*, are the minerals which have been thus altered.

Volcanic.

The real volcanic minerals are those which have been thrown out of the crater of a volcano. They are of three kinds; 1. Those substances which, having been thrown out from time to time, have formed the crater of the mountain: 2. Those which have been thrown out of the crater in a stream, and rolled down the mountain; they constitute *lavas:* 3. The water which is occasionally thrown out of volcanoes, containing ashes and other light substances, gradually evaporating, leaves the earthy matter behind it; this substance constitutes *volcanic tuff*.

SECT. III.

OF VEINS.

Nature of veins.

VEINS are mineral repositories which cut through the strata or beds of which a mountain is composed, and which are filled with substances more or less different from the rocks through which they pass. We shall have a very distinct notion of veins, if we suppose that the mountains in which they occur were split by some means or other, and that the rifts thus formed were filled up by the matter which constitutes veins. They are distinguished from *beds* by their direction, which is either perpendicular to the stratifications, or at least forms an angle with it.

Sometimes the strata through which veins pass are merely separated from each other; so that if we cut through the vein we find the same strata of the rock on both sides of it: but sometimes also the corresponding strata on one side are lower than on the other, as if the portion of the rock on one side of the vein had sunk a little, while the portion on the other side kept its original position. In such cases, the side of the rock against which the vein leans, or the *floor* of the vein, has always its strata highest up; while the strata of the portion of rock which leans over the vein, or the *roof* of the vein, are always lowest. So that this is the portion which appears to have sunk. Such a change of position in the strata is known in this country by the name of a *shift*.

In considering veins, there are two circumstances which claim our attention: namely, 1. The shape of veins; and, 2. The substances with which they are filled.

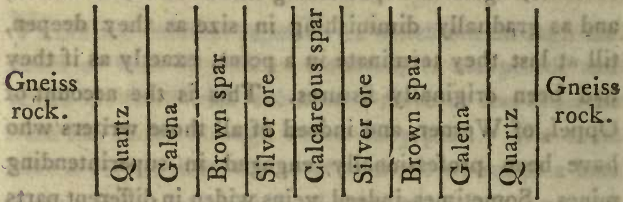
Their shape.

1. All those mineralogists who have had the best opportunity of examining the shape of veins with correctness, agree in representing them as widest above, and as gradually diminishing in size as they deepen, till at last they terminate in a point, exactly as if they had been originally fissures. This is the account of Oppel, of Werner, and indeed of all those writers who have been professionally engaged in superintending mines. Sometimes, indeed, veins widen in different parts of their course, and afterwards contract again to their former size; but more commonly they continue diminishing gradually to their extremity.

2. Sometimes these veins are either partially or entirely empty. In that case they are denominated *fissures*; but most commonly they are filled with a matter more or less different from the rock through which they pass. Sometimes the vein is filled up with one species of mineral. Thus we have veins of *calcareous spar*, *of quartz*, &c.; but when it is of any size, we frequently find a variety of substances: these are disposed in regular layers always parallel to the sides of the vein, and they follow in their position a very regular order. One species of mineral constitutes the centre of the vein: on each side of this central bed the very

Structure.

same *layers* occur in the same order from the centre to the side of the vein. To give an example; the vein *Gregorius*, at Freyberg, is composed of nine layers or beds. The middle of the vein consists of a layer of *calcareous spar;* on each side of this is a layer consisting of various ores of *silver* mixed together; on each side of this a layer of *brown spar;* on each side of this a layer of *galena;* on each side of this, again, and contiguous to the side of the vein, is a layer of *quartz*. The following sketch will give the reader some notion of the relative position of these layers:



Sometimes the number of layers of which a vein is composed greatly exceeds this. Werner describes one in the district of Freyberg, in which the middle layer is calcareous spar, having on each side of it no less than thirteen layers arranged in the very same order*.

Substances which they contain.

Almost every mineral substance which occurs in the mass of rocks has been found in veins. We sometimes find them filled with different well-known stony bodies. Thus veins of granite, porphyry, lime-stone, basalt, wacke, green-stone, &c. are not uncommon †; veins of quartz, clay, felspar, &c. are equally common.

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[*] *Nouvelle Theorie de la Formation des Filons*, p. 100.

[†] Werner, *Nouvelle Theorie*, p. 93.

Pit-coal and common salt, and almost all the metals, likewise occur in veins. Some veins are filled with water-worn pebbles, as one observed by Werner at Joachimstahl *. Some are filled with loam †. Nay, they even sometimes contain petrifactions. Thus Baron de Born describes a petrified porpites which he saw in a compact cinnabar vein in Hungary; and Mr de Schlottheim communicated an account of a still more remarkable appearance of the same kind to Werner. In a calcareous mountain in Thuringia, there occur veins of marl five or six inches thick, containing petrifactions differing altogether from those which are found in the lime-stone. The petrifactions found in the marl are, cornua ammonis, terebrates, and turbinites; while those that occur in the lime-stone rock are trochites. Beds of the marl occur in the neighbourhood; and these beds contain the same petrifactions that are found in the veins ‡.

Cross each other.

3. It is very common to find veins crossing each other in the same rock. When that happens, one of the veins may be traced passing through the other without any interruption, and cutting it in two, while the other always separates, and disappears at the point of crossing.

Werner's theory of veins.

4. Such is a short sketch of the most remarkable phenomena respecting veins. Werner supposes that they were originally fissures formed in the rocks, and that they were all gradually filled by minerals deposited slowly from above, while the rocks in which they occur were covered by water, and that they were filled at the same time that the different formations were deposi-

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* Werner, *Nouvelle Theorie*, p. 81. † Ibid. p. 82. ‡ Ibid. p. 88.

Book III.

ted. This theory he has supported in his book on Veins, by a very complete enumeration of all the circumstances respecting their structure and appearances. He has shown that they resemble fissures very exactly in their shape and direction ; and that as they contain petrifactions and minerals altered by the action of water, they must of necessity have been filled from above.

Veins of course, according to this theory, are newer than the rocks in which they occur ; and when two veins cross, that is obviously the newest which traverses the other without interruption, as the fissures constituting the second vein must have been formed after the first vein was filled up. When different veins contain the same minerals arranged in the same order, he conceives that they were filled at the same time, and says that such veins belong to the *same* formation. When they differ in these respects, they belong to different formations. From the position of the respective veins with respect to each other, he deduces their relative age ; and from this draws inferences respecting the relative age of the different mineral substances that occur in veins, similar to the inferences drawn respecting the age of the rocks which constitute the grand classes of formations described in the preceding Chapter. But for these curious and important consequences which he deduces from his theory, I must refer the reader to Werner's treatise, an English translation of which has been lately published by Dr Anderson.

I shall conclude this short sketch of Werner's Geognosy with Two Tables, exhibiting the different formations in which the most important stony bodies and ores occur, without distinguishing whether they are found in beds or in veins.

TABLE of Stones.

FORMATIONS.	Diamond	Zircon	Hyacinth	Chrysolite	Olivine	Coccolite	Augite	Vesuvian	Leucite	Melanite	Garnet	Granatite	Spinell	Sapphire	Emery	Corundum	Topaz	Emerald	Beryl	Schorl
1. Primitive							X	?						?			X			
2. Granite											X								X	X
3. Gneiss											X						X			X
4. Mica-slate											X	X					X	X		X
5. Clay-Slate											X	X			X			X		X
6. Primitive Trap						X														
7. Porphyry and Sienite		?									?					?				
8. Greywacke																	X			
9. Trans. Lime-stone																				
10. Transition Trap																				
11. Transition Flint-Slate																				
12. Old Red Sand-Stone																				
13. First floetz Lime-Stone																				
14. First Floetz Gypsum																				
15. Variegat. Sand-Stone																				
16. Second Floetz Gypsum																				
17. Shell Lime-stone																				
18. Third Lime-Stone																				
19. Chalk																				
20. Independent Coal																				
21. Floetz Trap	X	X	X		X		X		X	X			X	X						
22. Alluvial													X	X					X	X

TABLE of Stones.

FORMATIONS.	Pistasite	Schorl. Beryl	Axinite	Quartz	Iron-Flint	Horn-Stone	Flint	Chalcedony	Opal	Jasper	Chrysoprase	Obsidian	Pitch-Stone	Pearl-Stone	Pumice	Prehnite	Zeolite	Felspar	Porcel. Earth	Clay
1. Primitive																X	X			
2. Granite				X				?	X	X			X	X				X	X	
3. Gneiss	X	?	X	X	X	X	X	X	X	X			X					X	X	
4. Mica-Slate		X		X		X	X	X	X	X			X					X		
5. Clay-slate	X			X		X	X	X	X	X								X		
6. Primitive Trap	X		X	X												?	X	X		
7. Porphyry and Sienite				X		X		X	X	X	X	X	X	X	X			X		
8 Greywacke				X						X							X			
9. Trans. Lime-Stone																				
10. Transition Trap				X				X	X	X								X		
11 Transition Flint-Slate				X																
12. Floetz																				
13. Old Red Sand-Stone				X																
14. First floetz Lime-stone						X														
15. First Floetz Gypsum				X																
16. Variegat. Sand-Stone				X																
17. Second floetz Gypsum																				
18. Shell Lime-Stone						X	X													
19. Third Lime-Stone						X	X													
20. Chalk						X	X													
21. Independent Coal				X									X					X		
22. Floetz Trap	X			X		X	X	X	X	X		X	X	X	X	X	X	X		X
23. Alluvial				X		X	X	X		X									X	X

TABLE of Stones continued.

	Clay-Stone	Adhes. Slate	Polish Slate	Mica	Pot Stone	Chlorite	Hornblende	Clink Stone	Green Earth	Lithomarge	Ful. Earth	Steatite	Nephrite	Serpentine	Talc	Asbestus	Actinolite	Tremolite	Cyanite	Arragonite	Brown Spar	Dolomite	Rhomb-Spar	Swine-Stone	Marl
1																						X			
2				X		X		X				X	X								X				
3				X		X	X			X		X	X	X	X	X	X	X		X	X				
4				X		X	X							X	?		X	X	X		X				
5				X	X	X	X						X	X	X	X	X	X	X		X		X		
6						X	X				X										X				
7	X			X			X		X	X		X		X	X	X					X				
8				X								X				X				X	X				
9																				X					
10				X			X		X								X								
11																									
12		X									X														
13																					X				
14																									
15																								X	
16																									
17																				?					
18																									X
19																									
20																									
21	X			X			X	X	X	X											X				X
22				X			X	X	X	X		X						X			X				?
23			X	X							X														

TABLE *of Stones continued.*

FORMATIONS.	Apatite	Asparag. Stone	Phosphorite	Fluor Spar	Cube Spar	Carb. of Bar	Sulph. of Bar.	Carb. of Stron.	Sulph of Stron.	Boracite	Honey-Stone	Chriolite	Carb. of Soda	Common Salt	Sulphur	Amber	Mineral Pitch	Brown Coal	Black Coal	Glance Coal	Graphite
1. Primitive												X									
2. Granite	X		X	X			X	X									X				
3. Gneiss			X	X			X													X	X
4. Mica-Slate				X			X								X					X	X
5. Clay-slate		X		X			X													X	X
6. Primitive Trap	?	X					X														
7. Porphyry and Sienite				X			X								X						
8. Greywacke				X			X										X			X	?
9. Trans. Lime-Stone																					
10. Transition Trap							X										X				
11. Transition Flint-Slate							X														
12. Floetz		X							X												
13. Old Red Sand-Stone							X														
14. First floetz Lime-stone				X			X										X		X		
15. First Floetz Gypsum					X					X				X	X						
16. Variegat. Sand-Stone																					
17. Second floetz Gypsum				X																	
18. Shell Lime-Stone																					
19 Third Lime-Stone																					
20. Chalk																					
21. Independent Coal				X		X	X												X	X	X
22. Floetz Trap				X			X								X		X	X	X	X	
23. Alluvial											X				X	X		X			

TABLE of Metals.

FORMATIONS.	Gold	Platinum	Silver	Mercury	Palladium	Rhodium	Osmium	Iridium	Copper	Iron	Nickel	Tin	Lead
1. Primitive													
2. Granite	X		X						X	X	X	X	X
3. Gneiss	X		X						X	X	X	X	X
4. Mica-Slate	X		X						X	X	X	X	X
5. Clay-Slate	X		X	X					X	X	X	X	X
6. Porphyry	X		X						X	X		X	X
7. Greywacke	X		X						X	X			X
8. Trans. Lime-Stone	X									X			X
9. Transition Trap			X						X	X			
10. Flint-Slate													
11. Old Red Sand-Stone	X		X						X	X			
12. First Floetz Lime			X	X					X	X			
13. First Floetz Gypsum										X			
14. Variegat. Sand-Stone										X			
15. Second Floetz Gypsum										X			
16. Second Floetz Lime										X			
17. Third Floetz Lime													
18. Chalk										X			
19. Independent Coal	X		X	X					X	X			X
20 Floetz Trap									X	X			
21. Alluvial	X	X			X	X	X	X	X	X		X	

TABLE *of Metals continued.*

FORMATIONS.	Zinc	Bismuth	Antimony	Tellurium	Arsenic	Cobalt	Manganese	Chromium	Molybdenum	Uranium	Tungsten	Titanium	Columbrum	Cerium
1. Primitive														X
2. Granite	X	X			X	X	X		X	X	X	X		
3. Gneiss	X	X	X		X				X	X	X			
4. Mica-Slate	X	X	X		X	X			X	X	X	X		
5. Clay-Slate		X	X		X				X	X	X	X		
6. Porphyry		X		X	X		X				X			
7. Greywacke	X		X	X		X	X							
8. Trans. Lime-Stone	X			X			X							
9. Transition Trap														
10. Flint-Slate														
11. Old Red Sand-Stone														
12. First Floetz Lime						X								
13. First Floetz Gypsum					X									
14. Variegat. Sand-Stone														
15. Second Floetz Gypsum														
16. Second Floetz Lime														
17. Third Floetz Lime														
18. Chalk														
19. Independent Coal	X													
20 Floetz Trap												?		
21. Alluvial												X		

CHAP. IV.

OF THE ANALYSIS OF MINERALS.

Analyses of minerals.

The progress which the art of analysing minerals has made within these last twenty years is truly astonishing. To separate five or six substances intimately combined together, to exhibit each of them separately, to ascertain the precise quantity of each, and even to detect the presence and the weight of substances which do not approach $\frac{1}{500}$th part of the compound, would, at no very remote period, have been considered as a hopeless, if not an impossible, task; yet this can now be done with tolerable accuracy.

Begun by Margraf;

The first person who undertook the analysis of minerals was Margraff of Berlin. His attempts were indeed rude; but their importance was soon perceived by other chemists, particularly by Bergman and Scheele, whose industry and address brought the art to a considerable degree of perfection.

Improved by Klaproth,

But their methods, though they had very considerable merit, and, considering the state of the science, are wonderful proofs of the genius of the inventors, were often tedious and uncertain, and could not in all cases be applied with confidence. These defects were perceived by Klaproth, who applied himself to the analysis of minerals with a persevering industry which nothing could fatigue, and an ingenuity and accuracy which nothing could perplex. He corrected what was wrong, and supplied what was wanting, in the analytical method; invented new processes; discovered new instruments; and it is to his labours, more than to those of any other chemist, that the degree of perfection, to which the analysis of minerals has attained, is to be ascribed. Many improvements, however, were introduced by other chemists, especially by Vauquelin, whose analysis, both in point of accuracy and ingenuity, and in number, rival those of Klaproth himself.

And others.

I shall, in the following Sections, sketch out the methods of analysis at present practised. But it will be proper, in the first place, to premise the following observations.

Method of reducing a mineral to powder.

Before a mineral is submitted to analysis, it ought to be reduced to an impalpable powder. When the stone is extremely hard, it may be heated to redness, and then thrown into cold water. This makes it crack and break into pieces. If these pieces are not small enough, the operation may be repeated. These fragments are then to be beaten to small pieces in a polished steel mortar; the cavity of which should be cylindrical, and the steel pestle should fit it exactly, in order to prevent any of the stone from escaping during the act of pounding.

When the stone has been thus pounded, a certain quantity, whose weight is known exactly, 100 grains for instance, ought to be taken and reduced to as fine a powder as possible. This is best done by pounding small quantities of it at once, not exceeding five grains. The mortar employed is usually of agate. It may be about four inches in diameter, and rather more than an inch deep. The pestle is composed of the same ingredients. The powder is as fine as possible when it feels soft, adheres together, and as it were forms a cake under the pestle. It ought then to be weighed exactly. It will almost always be found heavier after being pounded than it was before ; owing to a certain quantity of the substance of the mortar which has been rubbed off during the grinding, and mixed with the powder. This additional weight must be carefully noted ; and after the analysis, a portion of the ingredients of the mortar, corresponding to it, must be subtracted. When the mortar is of agate or flint, the abstracted portion may be considered as pure silica.

Chemical vessels.

It is necessary to have a crucible of pure silver, or of platinum, capable of holding rather more than seven cubic inches of water, and provided with a cover of the same metal.

The dishes in which the solutions, evaporations, &c. are performed, ought to be of glass or porcelain. Those of porcelain are cheaper, because they are not so apt to break. Those which Mr Vauquelin uses are of porcelain ; they are sections of spheres, and are glazed both within and without, except that part of the bottom which is immediately exposed to the fire. In this country we commonly use Wedgewood's glazed evaporating dishes. The glaze is thin, and not so apt to crack as the glaze of the French porcelain ; but perhaps it does not resist quite so well the action of strong reagents.

SECT. I.

ANALYSIS OF EARTHS AND STONES*.

Ingredients of stones.

THE only substances which enter into the composition of the simple stones, as far at least as analysis has discovered, are the six earths, silica, alumina, zirconia, glucina, lime, and magnesia; and the oxides of iron, manganese, nickel, chromium, and copper†. Seldom more than four or five of these substances are found combined together in the same stone: we shall suppose, however, in order to prevent unnecessary repetitions, that they are all contained in the mineral which we are going to analyse.

Method of decomposing stones.

Let 100 or 200 grains of the stone to be analysed, previously reduced to a fine powder, be mixed with three times its weight of pure potash and a little water, and exposed in a silver crucible to heat. The heat should at first be applied slowly, and the matter should be constantly stirred, to prevent the potash from swelling and throwing any part out of the crucible. When the whole water is evaporated, the mixture should be kept for half an hour in a red heat.

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[*] See Vauquelin's Treatise on the Analysis of Stones, *Ann. de Chim.* xxx. 66.

[†] Barytes has also been discovered in one single stone, the *staurolite*: but its presence in stones is so uncommon, that it can scarcely be looked for. The method of detecting it shall be noticed afterwards.

If the matter in the crucible melts completely, and appears as liquid as water, we may be certain that the stone which we are analysing consists chiefly of silica; if it remains opaque, and of the consistence of paste, the other earths are most abundant; if it remains in the form of a powder, alumina is the prevalent earth *. If the matter in the crucible be of a dark or brownish red colour, it contains oxide of iron; if it is grass green, manganese is present; if it is yellowish green, it contains chromium.

When the crucible has been taken from the fire and wiped on the outside, it is to be placed in a capsule of porcelain, and filled with water. This water is to be renewed, from time to time, till all the matter is detached from the crucible. The water dissolves a part of the combination of the alkali with the silica and alumina

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* Mr Chenevix has lately suggested an ingenious method of analysing stones that do not fuse with potash. He put it in practice in analysing the different varieties of corundum. This mineral is composed almost entirely of alumina, and is extremely hard. Potash acts upon it very feebly; so that, in the common way of analysis, the process is very tedious, and the quantity of potash necessary very great. Mr Chenevix substituted borax in place of potash, which acts upon aluminous stones very readily. He mixed 100 grains of sapphire in powder with 250 grains of calcined borax, and exposed the mixture to a violent heat in a platinum crucible for two hours. The mass, when cold, had the appearance of a greenish blue glass, which adhered strongly to the crucible. The whole was boiled in muriatic acid for some hours, by which a complete solution was obtained. The whole of the earthy matter was then precipitated by means of ammonia not entirely saturated with carbonic acid; and the precipitate, after being well washed, was redissolved in muriatic acid. By this means the borax was got rid of. The analysis was then conducted nearly in the manner described in the text, excepting only that muriate of ammonia was employed to separate the alumina from potash.—*Phil. Trans.* 1802, p. 331.

of the stone; and if a sufficient quantity were used, it would dissolve the whole of that combination.

Muriatic acid is now to be poured in till the whole of the matter is dissolved *. At first a flaky precipitate appears, because the acid combines with the alkali which kept it in solution. Then an effervescence takes place, owing to the decomposition of some carbonate of potash formed during the fusion. At the same time the flaky precipitate is redissolved; as is also that part of the matter which, not having been dissolved in the water, had remained at the bottom of the dish in the form of a powder. This powder, if it consists only of silica and alumina, dissolves without effervescence; but if it contains lime, an effervescence takes place.

If this solution in muriatic acid be colourless, we may conclude that it contains no metallic oxide, or only a very small portion; if its colour be purplish red, it contains manganese; orange red indicates the presence of iron; and golden yellow the presence of chromium.

This solution is to be poured into a capsule of porcelain, covered with paper, and evaporated to dryness on a sand bath. When the evaporation is drawing towards its completion, the liquor assumes the form of jelly. It must then be stirred constantly with a silver or porcelain rod, to facilitate the disengagement of the acid and water, and to prevent one part of the matter from being too much, and another not sufficiently dried. Without this precaution, the silica and alumina would not be completely separated from each other.

When the matter is reduced almost to a dry powder,

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* Muriatic acid does not dissolve the mass completely if the stone consists chiefly of silica.

Separation of the silica,

a large quantity of pure water is to be poured on it; and, after exposure to a slight heat, the whole is to be poured on a filter. The powder which remains upon the filter is to be washed repeatedly, till the water with which it has been washed ceases to precipitate silver from its solutions. This powder is the *silica* which the stone that we are analysing contained. It must first be dried between folds of blotting paper, then heated red hot in a platinum or silver crucible, and weighed as soon as cold. It ought to be a fine powder, of a white colour, not adhering to the fingers, and entirely insoluble in acids. If it be coloured, it is contaminated with some metallic oxide; and shows that the evaporation to dryness has been performed at too high a temperature. To separate this oxide, the silica must be boiled with an acid, and then washed and dried as before. The acid solution must be added to the water which passed through the filter, and which we shall denominate A.

The watery solution A is to be evaporated till its quantity does not exceed an English pint. A solution of carbonate of potash is then to be poured into it till no more matter precipitates. It ought to be boiled a few moments to enable all the precipitate to fall to the bottom. When the whole of the precipitate has collected at the bottom, the supernatant liquid is to be decanted off; and water being substituted in its place, the precipitate and water are to be thrown upon a filter. When the water has run off, the filter, with the precipitate upon it, is to be placed between the folds of blotting paper. When the precipitate has acquired some consistence, it is to be carefully collected by an ivory knife, mixed with a solution of pure potash, and boiled in a porcelain capsule. If any alumina or glucina be present, they will be dissolved in the potash; while the other substances remain untouched in the form of a powder, which we shall call B.

Alumina.

Into the solution of potash as much acid must be poured as will not only saturate the potash, but also completely redissolve any precipitate which may have at first appeared. Carbonate of ammonia is now to be added in such quantity that the liquid shall taste of it. By this addition the whole of the alumina will be precipitated in white flakes, and the glucina will remain dissolved, provided the quantity of carbonate of ammonia used be not too small. The liquid is now to be filtered; and the alumina which will remain on the filter is to be washed, dried, heated red hot, and then weighed. To see if it be really alumina, dissolve it in sulphuric acid, and add a sufficient quantity of sulphate or acetate of potash; if it be alumina, the whole of it will be converted into crystals of alum.

Glucina,

Let the liquid which has passed through the filter be boiled for some time; and the glucina, if it contains any, will be precipitated in a light powder, which may be dried and weighed. When pure, it is a fine, soft, very light, tasteless powder, which does not concrete when heated, as alumina does.

Lime,

The residuum B may contain lime, magnesia, and one or more metallic oxides *. Let it be dissolved in weak sulphuric acid, and the solution evaporated to dryness. Pour a small quantity of water on it. The wa-

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* If yttria be suspected, let the residuum be treated with carbonate of ammonia, which will dissolve the yttria and leave the other bodies. Then proceed as above.

ter will dissolve the sulphate of magnesia and the metallic sulphates; but the sulphate of lime will remain undissolved, or, if any portion dissolve, it may be thrown down by the addition of a little weak alcohol. Let it be heated red hot in a crucible, and weighed. The lime amounts to 0·42 of the weight.

Let the solution containing the remaining sulphates be diluted with a large quantity of water; let a small excess of acid be added; and then let a saturated carbonate of potash be poured in. The oxides of chromium, iron, and nickel, will be precipitated, and the magnesia and oxide of manganese will remain dissolved. The precipitate we shall call C.

Manganese,

Into the solution let a solution of hydrosulphuret of potash be poured, and the manganese will be precipitated in the state of a hydrosulphuret. Let it be calcined in contact with air, and weighed. The magnesia may then be precipitated by pure potash, washed, exposed to a red heat, and then weighed.

Magnesia,

Chromium,

Let the residuum C be boiled repeatedly with nitric acid, then mixed with pure potash; and after being heated, let the liquid be decanted off. Let the precipitate, which consists of the oxides of iron and nickel, be washed with pure water; and let this water be added to the solution of the nitric acid and potash. That solution contains the chromium converted into an acid. Add to this solution an excess of muriatic acid, and evaporate till the liquid assumes a green colour; then add a pure alkali: The chromium precipitates in the state of an oxide, and may be dried and weighed.

Iron,

Let the precipitate, consisting of the oxides of iron and nickel, be dissolved in muriatic acid; add an excess

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of ammonia: The oxide of iron precipitates. Let it be washed, dried, and weighed.

Nickel.

Evaporate the solution, and the oxide of nickel will also precipitate, or the whole may be precipitated by adding hydrosulphuret of ammonia; and its weight may be ascertained in the same manner as the other ingredients.

The weight of all the ingredients obtained are now to be added together, and their sum total compared with the weight of the matter submitted to analysis. If the two are equal, or if they differ only by ·03 or ·04 parts, we may conclude that the analysis has been properly performed: but if the loss of weight be considerable, something or other has been lost. The analysis must therefore be repeated with all possible care. If there is still the same loss of weight, we may conclude that the stone contains some substance, which has either evaporated by the heat, or is soluble in water.

A fresh portion of the stone must therefore be broken into small pieces, and exposed in a porcelain crucible to a strong heat. If it contains water, or any other volatile substance, it will come over into the receiver; and its nature and weight may be ascertained.

If nothing comes over into the receiver, or if what comes over is not equal to the weight wanting, we may conclude that the stone contains some ingredient which is soluble in water.

To discover whether it contains a *fixed alkali*, which is very frequently found in simple stones, three methods of analysis have been followed.

Methods of separating fixed alkalies.

1. The stone, reduced to an impalpable powder, is cautiously heated repeatedly with sulphuric acid, and the mass digested in water. This solution, properly

concentrated, is set aside for some days. If crystals of alum make their appearance, we are sure that the mineral contained potash. The *potash* may be reckoned to amount to 0·104 of the weight of these crystals. If no crystals appear, the solution is to be evaporated to dryness, and the residue exposed to a moderate red heat. It is then to be digested in water, and the solution mixed with carbonate of ammonia, and filtered. It must be again evaporated to dryness, the residue exposed to a heat of 700°, and redissolved. The solution, by proper concentration, will yield crystals, either of sulphate of soda, or of potash, according to circumstances, and these are easily distinguished. Indeed the presence or absence of potash may be recognized by mixing the solution of the salt, obtained with a somewhat concentrated solution of nitro-muriate of platinum. If potash be present, the usual yellow precipitate of muriate of platinum-and-potash is obtained.

2. The method described in the last paragraph may be considered as a short abstract of the plans of analysis at first pursued by Vauquelin and Kennedy, to detect and distinguish fixed alkalies contained in minerals. The following method, invented by Klaproth, is much easier. He fused one part of the mineral under examination with four parts of nitrate of barytes, in a porcelain crucible. A spongy mass was obtained, which was of a light blue colour, and dissolved completely in diluted muriatic acid. The yellow coloured solution was mixed with a sufficient quantity of sulphuric acid, not only to precipitate the barytes, but to expel the muriatic acid, and the liquid was evaporated to dryness. The mass was digested in water, and then thrown upon a filter. The sulphate of barytes and si-

lica remained behind. The solution, which was limpid, was saturated with carbonate of ammonia, and filtered a second time. All the earthy and metallic bodies were now separated, and the solution contained only the sulphates of fixed alkali and ammonia. It was evaporated to dryness, and the salt put into a porcelain crucible, and exposed to a heat sufficient to expel the sulphate of ammonia. The residuum was dissolved in water, and crystallized. Pure fixed alkaline sulphate was obtained. It was dissolved in water, and decomposed by means of acetate of barytes. The solution was filtered to separate the sulphate of barytes formed, and the liquid evaporated to dryness. The salt thus obtained was acetate of fixed alkali. It was reddened in a crucible. The charry residue was dissolved in water, filtered, and crystallized. It was now a fixed alkaline carbonate, easily distinguished by its properties *.

3. The third method has been recently practised by Mr Davy. He fuses one part of the mineral under examination with two parts of boracic acid, dissolves the fused mass in diluted nitric acid, and concentrates the solution to separate the silica. The liquid is then mixed with carbonate of ammonia in excess, and boiled and filtered. By this means all the earthy and metallic ingredients are separated. The liquid is then mixed with a sufficient quantity of nitric acid, and evaporated till the whole of the boracic acid separates. Nothing now remains but the nitric acid, combined with the alkaline constituents of the mineral and with

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* *Beitrage*, iii. 240.

ammonia. The dry saline mass is freed from the nitrate of ammonia by a heat of 500° ; and the nitrate of potash or soda, which remains, may easily be recognized by its properties *.

How to separate fluoric acid.

But simple stones have been recently discovered to contain fluoric acid ; and the methods hitherto described are not sufficient to detect and appreciate the quantity of that substance. The method practised by Klaproth to detect the presence of this acid, is to heat the mineral containing it with sulphuric acid in a glass retort. The corrosion of the retort, and the siliceous deposite made on the water contained in the receiver, show sufficiently the presence of fluoric acid. To detect its quantity the mineral is fused with potash, and the silica separated as usual. The remaining liquid is precipitated by means of carbonate of potash ; and the liquid, being neutralized, is mixed with lime water. The precipitate of fluate of lime, thus obtained, is heated to redness. He estimates the fluoric acid contained in the mineral at 0·48 of this fluate of lime †.

Analysis of saline stones,

In this manner may simple stones and aggregates be analysed. As to saline stones, their analysis must vary according to the acid which they contain. But almost all of them may be decomposed by one or other of two methods ; of each of which I shall give an example.

1. *Analysis of Carbonate of Strontian.*

Of carbonates,

Klaproth analysed this mineral by dissolving 100 parts of it in diluted muriatic acid : during the solution

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[*] Nicolson's *Jour.* xiii. 86.

[†] Gehlen's *Jour.* iii. 595.

30 parts of carbonic acid escaped. The solution crystallized in needles; and when dissolved in alcohol burnt with a purple flame. Therefore it contained strontian. He dissolved a grain of sulphate of potash in six ounces of water, and let fall into it three drops of the muriatic solution. No precipitate appeared till next day. Therefore the solution contained no barytes; for if it had, a precipitate would have appeared immediately.

He then decomposed the muriatic acid solution by mixing it with carbonate of potash. Carbonate of strontian precipitated. By the application of a strong heat, the carbonic acid was driven off. The whole of the earth which remained was dissolved in water. It crystallized; and, when dried, weighed $69\frac{1}{2}$ *.

2. *Analysis of Sulphate of Strontian.*

Sulphates.

Vauquelin analysed an impure specimen of this mineral as follows:

On 200 parts of the mineral, diluted nitric acid was poured. A violent effervescence took place, and part of the mineral was dissolved. The undissolved portion, after being heated red hot, weighed 167. Therefore 33 parts were dissolved.

The nitric solution was evaporated to dryness: A reddish substance remained, which indicated the presence of oxide of iron. This substance was redissolved in water, and some ammonia mixed with it; a reddish precipitate appeared, which, when dried, weighed one, and was oxide of iron. The remainder of the solution was precipitated by carbonate of potash. The precipi-

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* Klaproth, *Beitrage*, i. 260.

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tate weighed, when dried, 20, and possessed the properties of carbonate of lime. Therefore 200 parts of this mineral contain 20 of carbonate of lime, one of oxide of iron, and the remainder of the 33 parts he concluded to be water.

The 167 parts, which were insoluble in nitric acid, were mixed with 500 parts of carbonate of potash and 7000 parts of water, and boiled for a considerable time. The solution was then filtered, and the residuum washed and dried. The liquid scarcely effervesced with acids; but with barytes it produced a copious precipitate, totally indissoluble in muriatic acid. Therefore it contained sulphuric acid.

The undissolved residuum, when dried, weighed 129 parts. It dissolved completely in muriatic acid. The solution crystallized in needles; when dissolved in alcohol, it burnt with a purple flame; and, in short, had all the properties of muriate of strontian. Therefore these 129 parts were carbonate of strontian. Now, 100 parts of this carbonate contain 30 of carbonic acid; therefore 129 contain 38·7. Therefore the mineral must contain in 200 parts 90·3 of strontian.

Now, the insoluble residuum of 167 parts was pure sulphate of strontian; and we have seen that it contained 90·3 of strontian. Therefore the sulphuric acid must amount to 76·7 parts *.

Nearly in the same manner as in the first of these examples may the analysis of carbonate of lime and barytes be performed; and nearly in the same manner with the second we may analyse the sulphates of lime and barytes.

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* *Jour. de Min.* No. xxxvii. I.

Phosphates,

Phosphate of lime may be dissolved in muriatic acid, the excess of acid may be driven off as far as possible, and the lime precipitated by oxalic acid ; and the oxalate, calcined in a platinum crucible, leaves the lime. The liquid solution may be evaporated to dryness, and then melted to a glass, which will give us the weight of the acid.

Fluates,

The fluate of lime may be mixed with sulphuric acid and distilled. The fluoric acid will come over in the form of gas. What remains in the retort, which will consist chiefly of sulphate of lime, may be analysed by the rules already laid down.

Borates.

The borate of lime may be dissolved in nitric or sulphuric acid : The solution may be evaporated to dryness, and the boracic acid separated from the residuum by means of alcohol, which will dissolve it without acting on any of the other ingredients. The remainder of the dry mass may be analysed by the rules laid down in this Section.

SECT. II.

OF THE ANALYSIS OF COMBUSTIBLES.

THE only combustibles of whose analysis it will be necessary to speak are coals and sulphur ; for the method of analysing the diamond and oil has already been given in the First part of this Work.

Method of analysing coal.

Coal is composed of charcoal, bitumen, and some portion of earth. The earths may be detected by burn-

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ing completely a portion of the coal to be analysed. The ashes which remain after incineration consist of the earthy part. Their nature may be ascertained by the rules laid down in Sect. I. of this Chapter.

For the method of ascertaining the proportion of charcoal and bitumen in coal, we are indebted to Mr Kirwan.

When nitre is heated red hot, and charcoal is thrown on it, a violent detonation takes place; and if the quantity of charcoal be sufficient, the nitre is completely decomposed. Now, it requires a certain quantity of pure charcoal to decompose a given weight of nitre. From the experiments of Lavoisier, it follows, that when the detonation is performed in close vessels under water, 13·21 parts of charcoal are capable of decomposing 100 parts of nitre *. But when the detonation is performed in an open crucible, a smaller proportion of charcoal is necessary, because part of the nitre is decomposed by the action of the surrounding air. Scheele found, that under these circumstances 10 parts of plumbago were sufficient to decompose 96 parts of nitre; and Mr Kirwan found, that nearly the same quantity of charcoal was sufficient for producing the same effect.

Macquer long ago observed that no volatile oily matter will detonate with nitre, unless it be previously reduced to a charcoal; and that then its effect upon nitre is precisely proportional to the charcoal which it contains †. Mr Kirwan, upon trying the experiment with *vegetable pitch* and *maltha*, found that these substances did not detonate with nitre, but merely burn

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* *Mem. Scav. Etrang.* xi. 626.

† Macquer's *Dictionary*, 2 edit. p. 481.

upon its surface with a white or yellow flame; and that after they were consumed, nearly the same quantity of charcoal was necessary to decompose the nitre which would have been required if no bitumen had been used at all *. Now coals are chiefly composed of charcoal and bitumen. It occurred therefore to Mr Kirwan, that the quantity of charcoal which any coal contains may be ascertained by detonating it with nitre: For since the bitumen of the coal has no effect in decomposing nitre, it is evident that the detonation and decomposition must be owing to the charcoal of the coal; and that therefore the quantity of coal necessary to decompose a given portion of nitre will indicate the quantity of carbon which it contains: and the proportion of charcoal and earth which any coal contains being ascertained, its bituminous part may be easily had from calculation.

The crucible which he used in his experiments was large; it was placed in a wind furnace at a distance from the flue, and the heat in every experiment was as equal as possible. The moment the nitre was red hot, the coal, previously reduced to small pieces of the size of a pinhead, was projected in portions of one or two grains at a time, till the nitre would no longer detonate; and every experiment was repeated several times to ensure accuracy.

He found that 480 grains of nitre required 50 grains of Kilkenny coal to decompose it by this method. Therefore 10 grains would have decomposed 96 of nitre; precisely the quantity of charcoal which would

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* *Miner.* ii. 522.

have produced the same effect. Therefore Kilkenny coal is composed almost entirely of charcoal.

Cannel coal, when incinerated, left a residuum of 3·12 in the 100 parts of earthy ashes. 66·5 grains of it were required to decompose 480 grains of nitre; but 50 parts of charcoal would have been sufficient: therefore 66·5 grains of cannel coal contain 50 grains of charcoal and 2·08 of earth; the remaining 14·42 grains must be bitumen. In this manner may the composition of any other coal be ascertained.

As for sulphur, in order to ascertain any accidental impurities with which it may be contaminated, it ought to be boiled in thirty times its weight of water, afterwards in diluted muriatic acid, and lastly treated with nitro-muriatic acid. These substances will deprive it of all its impurities without acting on the sulphur itself, at least if the proper cautions be attended to. The sulphur may then be dried and weighed. The deficiency in weight will mark the quantity of the substances which contaminate the sulphur. The solutions may be evaporated and examined, according to the rules laid down in the First and Third Sections of this Chapter.

SECT. III.

ANALYSIS OF ORES.

No general method.

THE diversity of metallic ores is so great, that no general method of analysis can be given. Let us therefore follow the different orders, one by one, and point out the proper method of analysing each. In the rules which I propose to give I shall follow Bergman, to whom we are indebted for the first precise treatise on the analysis of ores, except when his methods have been superseded by the improvements of succeeding chemists.

1. *Gold Ores.*

Analysis of native gold.

The presence of gold may easily be detected by treating the mineral supposed to contain it with nitro-muriatic acid, and dropping muriate of tin into the solution. If the solution contains any gold, a purple precipitate immediately appears.

Native gold ought to be dissolved in nitro-muriatic acid: the silver, if any be present, falls to the bottom in the state of muriate, and may be separated by filtration, and weighed. Pour sulphate of iron into the solution, and the gold is precipitated in the metallic state, The copper, if any be present, may be precipitated by means of a plate of iron. The presence of iron may be ascertained by dropping tincture of nutgalls into a portion of the solution *.

The auriferous pyrites may be treated with diluted nitrous acid, which dissolves the iron and separates the sulphur. The gold remains insoluble, and is found in the state of small grains.

2. *Ores of Platinum.*

The grains of crude platina, which constitute the only ore of this metal, are exceedingly complex in their

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* Bergman, ii. 410.

nature, containing not fewer than eight metals, and sometimes even more. These are mercury, gold, platinum, iron, palladium, rhodium, osmium, and iridium.

The mercury may be driven off by heat, and the gold then becomes visible, and may be picked out, as it is in grains merely mixed with the others. The iron exists, in part at least, in the state of iron-sand, and may be separated by the magnet. The portion combined with the platinum, if there be any such, is not so easily separated. The ore thus purified is mixed with diluted nitro-muriatic acid, which dissolves the rest of the gold. Strong nitro-muriatic acid, assisted by heat, dissolves the platinum, the palladium, and the rhodium. The black powder and the metallic scales which remain undissolved are composed of osmium and iridium, which may be separated by the alternate action of potash and muriatic acid. No good method is known of separating the portion of these metals, which dissolves along with the platinum without loss. The platinum is precipitated by a concentrated solution of muriates of ammonia, and the palladium by a solution of prussiate of mercury. The rhodium is obtained by adding common salt to the solution thus freed from the other metals, evaporating to dryness, and digesting the dry mass in alcohol. For a fuller account of these processes, the reader is referred to the dissertations of Wollaston, Tennant, Desfontaines, Fourcroy, and Vauquelin*.

3. *Ores of Silver.*

The analysis of the ores of silver has been always

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* See these dissertations quoted in Vol. I. of this Work, under the head of the respective metals.

considered as very important, on account of the great value of the metal which they contain in greater abundance.

Analysis of native silver,

1. Native silver is to be dissolved in nitric acid. The gold, if the ore contains any, remains in the state of a black powder, and may be dried and weighed. The silver may be precipitated by common salt. One hundred parts of the precipitate dried denote about 75 parts of silver. The presence of copper may be ascertained by the greenish blue colour of the solution, and by the deep blue colour which it assumes on adding ammonia. The copper may be precipitated by a plate of iron, or by the rules laid down hereafter. When the ore contains arsenic, its proportion may be estimated by weighing before and after fusion; for the arsenic is dissipated by heat, or the ore may be dissolved as before in nitric acid, which acidifies the arsenic. After the separation of the silver, the arsenic acid may be precipitated by nitrate of lead, 100 parts of the dry precipitate indicating about 22 of arsenic.

Antimonial silver,

2. Alloy of silver and antimony is to be treated with nitric acid, which dissolves the silver and oxidizes the antimony. The silver is estimated as above. The oxide of antimony is to be dissolved in muriatic acid, and the metal thrown down by means of a plate of iron *.

Sulphuret,

3. Sulphuret of silver is to be treated with diluted nitric acid, which dissolves the silver, leaving the greater part of the sulphur untouched. The residuum is to be dried, and then the sulphur burnt off. The loss of weight gives the sulphur. The residuum, if any, is

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* Klaproth, iii. 175.

undecomposed sulphuret, to be treated as at first. The silver is to be precipitated by common salt; and the other metals, if any be present, may be ascertained as above. Part of the sulphur is always acidified. The acid thus formed may be precipitated by nitrate of barytes, 100 parts of the dried precipitate indicating about 14·5 of sulphur *.

Antimoniated silver.

4. Antimoniated silver ore was analysed by Klaproth in the following manner: 100 parts of it were boiled in diluted nitric acid. The residuum, washed and dried, was 26. These 26 were digested in nitro-muriatic acid. The residuum now weighed 13 (so that 13 had been dissolved), 12 of which were sulphur, and burnt away, leaving behind them one part of silica. The nitro-muriatic solution, when diluted largely with water, let fall a precipitate which weighed 13 (or 10 of pure antimony), and had the properties of oxide of antimony; for they did not evaporate till heated to redness, but at that temperature were dissipated in a grey smoke.

The nitric solution was green. Common salt occasioned a precipitate which weighed 87·75, equivalent to 65·81 of pure silver. After the separation of this muriate of silver, sulphate of soda occasioned no precipitate. Therefore the solution contained no lead. When supersaturated with soda, a grey precipitate fell, weighing five parts. On burning coals this precipitate gave out an arsenical smell. It was redissolved in nitric acid; sulphureted alkali occasioned a smutty brown precipitate; and prussic alkali a prussian blue, which,

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* Klaproth, i. 172.

after torrefaction, was magnetic. Hence he concluded, that these five parts were a combination of iron and arsenic acid.

The nitric solution which had been supersaturated with ammonia was blue; he therefore suspected that it contained copper. To discover this, he saturated it with sulphuric acid, and put into it a polished plate of iron. The quantity of copper was so small, that none could be collected on the iron *.

Black silver ore,

5. Black silver ore may be analysed as No. 2. separating the copper, if any be present, by means of an iron plate, and estimating the carbonic acid that escapes when the ore is heated or dissolved in nitric acid.

Red silver ore,

6. Red silver ore was analysed by Vauquelin in the following manner: One hundred parts of it were digested in 500 parts of nitric acid previously diluted with water †. The undissolved residuum, being washed and dried, weighed 42·06. Being treated with muriatic acid, it was all dissolved except 14·66 parts, which were sulphur. The muriatic solution, when diluted with a great quantity of water, deposited a white powder, which weighed 21·25, and was oxide of antimony. The nitric acid solution remained still to be examined. Muriatic acid occasioned a heavy precipitate, which weighed 72·66 parts, and which was muriate of silver. Reagents showed that the acid retained no other substance in solution ‡.

Muriate,

8. Muriate of silver was analysed by Klaproth in the

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* Klaproth's *Beitrage*, i. 163.

† No effervescence occurred during the solution; a proof that the metals existed in the ore in the state of oxides.

‡ *Jour. de Min.* No. xvii. p. 2.

following manner: One hundred parts of it were mixed with thrice their weight of pure carbonate of potash, and melted together in a glass retort. The mass was dissolved in water, and the solution filtered. A residuum remained, which was dissolved in nitric acid, with the exception of a red powder; which, treated with nitro-muriatic acid, was dissolved, except a little muriate of silver, which, when reduced, yielded ·5 of pure silver. Ammonia precipitated from the nitro-muriatic solution 2·5 parts of oxide of iron. The nitric solution was precipitated by common salt; the muriate of silver, thus obtained, yielded, when reduced, 67·25 of pure silver.

The original aqueous solution of the alkaline mass was saturated with acetic acid, on which it deposited 1·75 parts of alumina. The solution was evaporated to dryness, and the dry mass treated with alcohol, which dissolved the acetate of potash. The residuum, amounting to 58·75 parts, was dissolved in water; and being treated with muriate of barytes, 15 parts of sulphate of barytes precipitated, indicating the presence of about ·5 of sulphuric acid, or 0·75 sulphate of potash. The remaining 58 parts were muriate of potash, indicating about 21 parts of muriatic acid *.

4. *Ores of Mercury.*

Native mercury,

1. Native mercury and amalgam may be dissolved in nitric acid. The gold, if any be present, remains in the state of powder, and may be estimated by its weight. The affusion of water precipitates the bismuth, if the

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* Klaproth, *Beitrage*, i. 132.

solution happens to contain any. Common salt precipitates the silver, and also part of the mercury; but the latter may be redissolved by a sufficient quantity of water, or, which is far better, of oxy-muriatic acid, while the muriate of silver remains insoluble. Lastly, the mercury may be precipitated by sulphate of iron, and estimated *. Or the mercury may be separated at once from the ore by distillation.

Cinnabar,

2. Cinnabar may be dissolved in muriatic acid, assisted by the gradual addition of nitric acid. The sulphur partly separates, and may be weighed, and is partly converted into sulphuric acid; which may be separated by muriate of barytes, and the portion of sulphur ascertained. The mercury may be separated by distilling a portion of the ore with half its weight of iron filings †.

Hepatic ore,

3. The analysis of the hepatic ore is conducted in a similar way. The small portion of foreign bodies are to be ascertained by the processes already laid down ‡.

Muriate,

4. Muriate of mercury may be digested in muriatic acid till the whole is dissolved. Muriate of barytes precipitates the sulphuric acid, 100 parts of which are equivalent to 186 of sulphate of mercury; and the proportion of this salt being known, we have that of the muriate §. Or, perhaps, a better mode of analysis would be to boil the salt with carbonate of potash till it is decomposed.

5. *Ores of Copper.*

Native copper,

1. Native copper sometimes contains gold, silver, or

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* Bergman, ii. 421.

† Klaproth, Gehlen's *Jour.* v. 436.

‡ See the analysis by Klaproth, Gehlen's *Jour.* v. 437.

§ Bergman, ii. 423.

iron. It may be dissolved in nitric acid; the gold remains in the state of a blackish or rather violet coloured powder; the silver may be separated by a polished plate of copper (or it may be precipitated from a separate portion of the solution by common salt); the iron may be separated by boiling the solution to dryness, and treating the residuum with water. By this process, the nitrate of iron is decomposed; the oxide of iron remains, while the water dissolves the nitrate of copper [*]. This last salt may be decomposed by boiling it with potash: the precipitate, dried in a red heat, is black oxide of copper. One hundred parts of it denote 80 of metallic copper [†].

Sulphuret,

2. Sulphuret of copper may be dissolved in muriatic acid by the help of nitric acid. Part of the sulphur separates, part is acidified. The solution being divided into two parts; from the one the copper may be precipitated by an iron plate, and from the other the iron by ammonia [‡]. The variegated copper ore, and copper pyrites, yield to the same mode of analysis.

Grey copper ore,

3. Grey ore of copper was thus analysed by Klaproth. Heated to redness in a retort, the sulphur and arsenic were driven off. The sublimate, being weighed, was digested in potash, which separated the sulphur, and left the arsenic. The roasted ore was then dissolved in nitric acid, except a small portion which yielded to muriatic acid. These solutions being mixed, a little muriate of silver fell, which was separated and reduced. The solution, mixed with sulphuric acid, was evaporated to dryness, and redissolved in water.

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[*] Bergman, ii. 427.

[†] Chenevix, *Phil. Trans.* 1801, p. 209.

[‡] Klaproth, ii. 279.

Ammonia threw down the iron from this solution, and a plate of zinc the copper *.

Red copper ore,

4. Red copper ore has only to be dissolved in muriatic acid, and the copper precipitated by a plate of iron ; 88 parts of the precipitated copper being equivalent to 100 of the orange oxide of which the ore is composed.

5. The analysis of the oxides and carbonates of copper scarcely requires any remarks. The water and carbonic acid must be estimated by distillation in close vessels, and collecting the products. The ore may then be dissolved in nitric acid, and its copper ascertained as above.

Arseniate,

6. Arseniate of copper was analysed by Mr Chenevix in the following manner : The ore was dissolved in diluted nitric acid, and nitrate of lead poured in. The solution was evaporated till a precipitate began to appear, and then mixed with alcohol. Arseniate of lead precipitated. One hundred parts of this salt indicate 33 of arsenic acid. The copper was separated from the nitric acid by boiling it with potash †.

4. *Ores of Iron.*

Notwithstanding the great variety of iron ores, they may be all, as far as analysis is concerned, arranged under three heads ; namely, 1. Sulphurets ; 2. Oxides ; and, 3. Salts.

Pyrites,

1. Pyrites, or sulphureted iron, may be treated repeatedly with boiling nitric acid till the sulphur is acidified. Muriatic acid is then to be added, and the di-

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* Gehlen's *Jour.* v. 5.

† *Phil. Trans.* 1801, p. 195.

gestion continued till the whole be dissolved *. Muriate of barytes is then to be added to precipitate the sulphuric acid ; 100 of the dried precipitate indicates 14·5 of sulphur. If the solution contains only iron, it may be precipitated by carbonate of soda, calcined to redness, and weighed. But if earths or manganese be present, we must proceed by the rules laid down in the First Section of this Chapter.

Oxides,

2. If the oxides of iron be pure, that is to say, contain nothing but iron, we have only to dissolve them in muriatic acid, and precipitate them as above. But it is very seldom that ores possess this perfect degree of purity. The iron is usually combined with manganese, alumina, silica, or with all of these together. The analysis is to be conducted exactly according to the rules laid down in the First Section of this Chapter.

3. The sparry iron ore may be analysed in the same manner, excepting only that the carbonic acid gas must be separated by distillation or solution in close vessels, and estimated by the rules laid down in the Fourth Chapter of the last Book †.

Arseniate,

4. Arseniate of iron was analysed by Mr Chenevix in the following manner : One hundred parts of it were boiled with potash till the arsenic acid was separated. Nitrate of lead was mixed with the solution ; 100 parts of the precipitate indicated 33 of arsenic acid. That portion of the ore which eluded the action of the potash was treated with muriatic acid ; the undissolved resi-

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* If any siliceous gangue be mixed with the ore, of course it will remain undissolved, and must be analysed according to the rules laid down in the First Section of this Chapter.

† See Vol. IV. p. 157.

duum was silica. The muriatic acid was supersaturated with ammonia. The iron precipitated; but the copper was dissolved by the ammonia[*].

7. *Ores of Tin.*

For the method of analysing the ores of tin we are indebted solely to Klaproth; the mode of analysis indicated by Bergman does not succeed.

Sulphuret,

1. The sulphuret of tin was thus analysed by Klaproth: 120 parts of the ore were digested with nitro-muriatic acid. 43 parts remained undissolved. Of these, 30 burnt away with a blue flame, and were sulphur; of the remaining 13, eight dissolved in nitro-muriatic acid. The undissolved five were heated with wax, and yielded a grain of iron attracted by the magnet. The rest was a mixture of alumina and silica. The nitro-muriatic solution was completely precipitated by potash, and the precipitate redissolved in muriatic acid. A cylinder of tin precipitated 44 parts[†] of copper from this solution, and lost itself 89 parts of its weight. A cylinder of zinc precipitated 130 parts of tin; so that, deducting the 89 parts of tin dissolved during the precipitation of the copper, 41 remain for the tin contained in the ore[‡].

Tinstone.

2. Tinstone was thus analysed by the same celebrated chemist. One hundred parts of the ore were heated to redness, with 600 parts of potash, in a silver crucible; and the mixture being treated with warm water, 11 parts remained undissolved. These 11, by a repe-

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[*] *Phil. Trans.* 1801, p. 219.

[†] One part of this was found to be tin, by digesting it in nitric acid.

[‡] *Observations on the Fossils of Cornwall*, p. 38. English Translation.

tition of the treatment with potash, were reduced to $1\frac{1}{4}$th. This small residuum dissolved in muriatic acid. Zinc precipitated from the solution one-half part of tin, and the Prussian alkali gave a blue precipitate, which indicated one-fourth part of iron.

The alkaline solution was saturated with muriatic acid; a white precipitate appeared, but it was redissolved by adding more acid. The whole was precipitated by carbonate of soda. The precipitate, which had a yellowish colour, was redissolved in muriatic acid: and a cylinder of zinc being inserted into the solution, 77 of tin were obtained, indicating nearly 98 parts of oxide of tin[*].

8. *Ores of Lead.*

Sulphuret,

1. Sulphuret of lead usually contains a little silver, and sometimes also antimony and zinc. It may be treated with diluted nitric acid, which leaves only the sulphur undissolved, the weight of which is to be taken, and its purity determined by combustion. If antimony be present, it will either remain in the state of a white oxide, or, if dissolved, it will be precipitated by diluting the solution with water. Muriatic acid is to be added, and the solution evaporated till it is reduced to a small portion. Muriate of lead and of silver precipitate. The first of these may be dissolved in boiling water, the second remains insoluble. Westrumb separated the muriate of silver by digesting the precipitate with ammonia. The liquid from which the muriates were separated may contain iron, zinc, copper. The

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[*] *Beitrage*, ii. 254.

iron may be precipitated by ammonia added in excess; the copper, by a plate of zinc: the zinc may be precipitated by carbonate of soda, reduced to the metallic state, and weighed; subtracting what had been separated from the plate of zinc.

Arseniated lead,

2. Arseniated lead was thus analysed by Vauquelin: 100 parts roasted for half an hour, and occasionally treated with a little tallow, lost 38 parts, which were considered as oxide of arsenic. The residue was treated with concentrated muriatic acid, and boiled in it for a quarter of an hour. The liquid assumed a red colour, and emitted abundance of oxymuriatic acid gas. A white needleform salt was deposited, and some of it was obtained by evaporation. This salt, dissolved in water, and treated with sulphate of soda, yielded 25 parts of sulphate of lead, = 20·2 parts of lead. The liquor thus freed from lead was treated with ammonia. The precipitate obtained weighed 39 parts. It consisted of oxide of iron mixed with oxide of arsenic. The production of oxymuriatic acid induced Vauquelin to consider the lead as in the state of peroxide *.

Carbonate,

3. Carbonate of lead was thus analysed by Klaproth: One hundred grains were thrown into 200 grains of nitric acid diluted with 300 grains of water. It dissolved completely with effervescence. The loss of weight was 16 grains. It was equivalent to the carbonic acid. The solution, which was colourless, was diluted with water, and a cylinder of zinc put into it. In 24 hours the lead was precipitated in the metallic state. It weighed 77 grains, = 82 grains oxide.

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* *Ann. de Chim.* xlii. 86.

If muriatic acid be suspected, it may be easily detected, and its weight ascertained by means of nitrate of silver.

Sulphate,

4. Sulphate of lead was thus analysed by Klaproth: One hundred grains of the ore, heated to redness, lost two grains, which were considered as water. It was then mixed with 400 grains of carbonate of potash, and heated to redness in a platinum crucible. The reddish yellow mass thus obtained was digested in water, and the whole thrown on a filter. The oxide of lead thus obtained weighed 72 grains. It was dissolved in diluted nitric acid. One grain of oxide of iron remained behind. Into the solution a cylinder of zinc was put. The lead thrown down weighed 66½ grains. The alkaline solution was supersaturated with nitric acid, and then treated with acetate of barytes. The sulphate of barytes obtained weighed 73 grains, which Klaproth considers as indicating 25 grains of sulphuric acid *.

Phosphate,

5. Phosphate of lead was thus analysed by Klaproth: One hundred grains were dissolved in diluted nitric acid. Nitrate of silver dropt into the solution formed a precipitate weighing 11 grains, = 1·7 grain muriatic acid. The solution was mixed with sulphuric acid. The sulphate of lead precipitated weighed 106 grains, = 78·4 oxide of lead. The solution was freed from sulphuric acid by means of nitrate of barytes, and then almost neutralized with ammonia. Acetate of lead was then dropt in. The phosphate of lead which precipitated weighed 82 grains, = 18·37 phosphoric acid. The solution was now mixed with muriatic acid, evaporated

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* *Beitrage*, iii. 163.

to dryness, and the dry mass washed in alcohol. The alcohol, when evaporated, left a small residue, which dissolved in water, and formed Prussian blue with prussiate of potash. It contained about $\frac{1}{10}$ grain of oxide of iron *.

Molybdate.

6. Molybdate of lead was thus analysed by Mr Hatchett. The ore was boiled repeatedly with sulphuric acid till the acid refused to dissolve any more. The solution contained the molybdic acid. The undissolved powder (sulphate of lead) was boiled for an hour with carbonate of soda, and then washed. Nitric acid now dissolved it, except a little silica. The lead was precipitated from this solution by sulphuric acid; after which ammonia separated a little oxide of iron. The sulphuric acid solution was diluted with 16 parts of water, and saturated with ammonia; a little oxide of iron gradually precipitated. The solution was now evaporated to dryness, and the mass strongly heated to separate the sulphate of ammonia. The residuum repeatedly treated with nitric acid was converted into yellow molybdic acid.

9. *Ores of Nickel.*

No exact method of analysing the ores of nickel has as yet been published.

Copper nickel,

1. Copper nickel may be dissolved in nitric acid, by which the greatest part of the sulphur will be separated. The arsenic may be afterwards precipitated by the affusion of water. A plate of iron will expel the copper, if any be present. Precipitate by potash add-

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* *Beitrage*, iii. 151.

ed in excess, and boil the precipitate, which will separate the arsenic and sulphur completely. Dissolve the precipitate (previously exposed moist for some time to the air) in acetic acid, and add an excess of ammonia. The iron is precipitated ; but the cobalt and nickel remain in solution. Evaporate, and the cobalt is deposited ; then by continuing the evaporation to dryness the nickel is obtained.

10. *Ores of Zinc.*

Blende.

1. Blende may be treated with diluted nitric acid, which will separate the sulphur, the siliceous gangue, &c. The purity of the sulphur is to be ascertained by combustion, and the residuum analysed in the manner formerly described. Precipitate the nitric solution by soda, redissolve in muriatic acid, precipitate the copper (if any be present) by a plate of iron ; separate the iron by adding an excess of ammonia *. The zinc now only remains in the solution, which may be obtained by evaporating to dryness, redissolving in muriatic acid, and precipitating by soda.

Calamine.

2. Calamine may be digested in nitric acid, noting the loss of weight for carbonic acid, and the insoluble residuum boiled with muriatic acid repeatedly ; what remains after dilution with boiling water is silica. The nitric solution contains zinc, and probably also iron and alumina ; evaporate to dryness, redissolve, and add an excess of ammonia. The iron and alumina either remain undissolved or are precipitated, and they may be separated by potash. The zinc may be precipitated by

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* Boil this precipitate in potash, to separate the alumina.

an acid, or by evaporation to dryness. The muriatic solution probably contains iron and alumina, which may be precipitated by the rules already laid down.

11. *Ores of Antimony.*

Native antimony,

1. Native antimony was thus analysed by Klaproth: One hundred grains were digested in nitric acid till the whole was converted into a white powder. When the acid emitted no longer any nitrous gas, the mixture was diluted with water and thrown upon a filter. The solution was then treated with nitrate of silver. The precipitate yielded by reduction one grain of silver. The prussiate of potash threw down from the residuum solution a precipitate which contained $\frac{1}{4}$th grain of iron. The white oxide formed by the nitric acid was digested in muriatic acid; the whole dissolved and formed a transparent solution. It was diluted with six times its weight of water, and the precipitate redissolved in muriatic acid, and a cylinder of zinc put into it. The antimony obtained weighed 98 grains *.

Sulphuret,

2. Sulphuret of antimony is to be treated with nitro-muriatic acid. The sulphur and the muriate of silver (if any silver be present) will remain. Water precipitates the antimony; sulphuric acid, the lead; and ammonia, the iron.

Red ore of antimony,

3. Klaproth analysed the red ore of antimony as follows: One hundred grains were digested in muriatic acid till the whole dissolved, except $1\frac{1}{2}$ grain of sulphur. A little sulphuret of antimony rose with the sulphureted hydrogen gas exhaled, and was deposited in the beak of

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* Klaproth, iii. 171.

the retort. The solution was diluted with water. The whole precipitated in the state of a white powder; for potash threw nothing from the liquid. The powder was redissolved in muriatic acid, an excess added, and the solution diluted. A plate of iron threw down 67½ grains of antimony. The ore then contained 78·3 grains of oxide of antimony. One hundred grains of the ore yielded by solution in muriatic acid 37 cubic inches of sulphureted hydrogen gas. From this Klaproth concluded that it contained 20 grains of sulphur *.

12. *Ores of Bismuth.*

Native bismuth,

Native bismuth may be treated with nitric acid. Repeated concentrations and affusions of water precipitate the bismuth, and perhaps the arsenic; but this last may be redissolved in boiling water. The cobalt remains, and may be examined by the rules to be hereafter laid down. The same analysis succeeds with the other ores of bismuth. The sulphur when present remains undissolved.

I shall give, as an example of these ores, Klaproth's analysis of a sulphuret of bismuth. Fifty grains of the ore were digested in nitric acid. The whole was dissolved except 2½ grains of sulphur. The solution being diluted with water, a white powder precipitated. The filtered solution was treated with common salt: at first it produced no change, but by and bye the whole became milky. The precipitate consisted, like the last, of oxide of bismuth. The solution continuing clear

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* *Beitrage*, iii. 179.

for some time, indicated that no silver was present. The white precipitate was not altered by exposure to the light; an additional proof that no silver was present *.

13. *Ores of Tellurium.*

White gold ore,

Klaproth dissolved the white gold ore of Fatzbay in nitro-muriatic acid, and added potash in excess to the solution. A brown precipitate remained undissolved, which was a mixture of gold and iron. It was redissolved in nitro-muriatic acid, the gold first precipitated by nitrate of mercury, and then the iron by potash. The potash in the first solution being saturated with muriatic acid, the oxide of tellurium precipitated †.

The other ores may be analysed in the same manner; only the precipitate occasioned by the potash must be treated according to the metals of which it consists. The rules have been already laid down.

14. *Ores of Arsenic.*

Native arsenic,

1. Native arsenic may be treated with nitro-muriatic acid. The silver and gold remain; the first in the state of a muriate; the second may be dissolved by means of nitro-muriatic acid, and precipitated by sulphate of iron. The arsenic may be precipitated by concentrating the nitric solution, and then diluting with water. The iron may then be precipitated by ammonia.

Sulphurets,

2. The sulphureted ores of arsenic may likewise be treated with diluted nitro-muriatic acid. The sulphur remains undissolved; the arsenic may be precipitated

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* *Beitrage*, i. 255.

† Crell's *Annals*, 1798. i. 95.

by concentration and the affusion of water ; the iron by ammonia.

Oxide,

3. Oxide of arsenic may be dissolved in 16 parts of water. The solution displays acid properties, and nitrate of silver and of mercury occasion precipitates in it.

15. *Ores of Cobalt.*

White cobalt ore,

1. White cobalt ore was thus analysed by Tassaert. To ascertain the proportion of arsenic, he treated the ore with diluted nitric acid, and obtained a complete solution. Crystals of white oxide of arsenic were deposited, and by repeated evaporations he separated the whole of the arsenic, and ascertained its weight. He then boiled a new portion of the ore with four times its weight of nitric acid, and thus acidified the arsenic, and obtained a solution. This solution was treated with potash, which retained the arsenic acid, and separated the other bodies. A precipitate of arseniate of cobalt, which had fallen when the nitric solution was diluted with water, was treated with potash for the same reason. The residuum, together with the precipitate occasioned by the potash, was dissolved in nitric acid, and ammonia added in excess. Part was retained in solution by the ammonia ; but part was precipitated. The precipitate was dissolved in acetic acid, and the solution repeatedly evaporated to dryness. By this process the oxide of iron gradually separated in the form of a red powder. The dissolved part was acetate of cobalt. It was decomposed by the addition of ammonia in excess, which redissolved the cobalt. By these processes the arsenic and iron were separated ; the cobalt was retained by the ammonia, and was obtained by evapora-

tion. To ascertain the proportion of sulphur in the ore, a new portion was boiled with nitric acid. On cooling, crystals of white oxide of arsenic were deposited. These being separated, nitrate of barytes was added to the solution; 100 parts of the dried precipitate indicated 14·5 of sulphur *.

The other ores of cobalt may be analysed nearly in the same way.

16. *Ores of Manganese.*

Barytated manganese,

1. Barytated manganese was treated by Vauquelin with muriatic acid; oxy-muriatic gas passed over, and the whole was dissolved except a little charcoal and silica. The solution when evaporated yielded crystals of muriate of barytes. These were separated; and the liquid, evaporated to dryness, yielded a yellow mass soluble in alcohol, and tinging its flame with yellow brilliant sparks. The proportion of barytes was ascertained by precipitating it in the state of a sulphate; the manganese, by precipitating it by carbonate of potash †.

Grey ore of manganese,

2. The grey ore of manganese was treated by the same chemist with muriatic acid; some silica remained undissolved. Carbonate of potash was added to the solution. The precipitate was at first white, but became black when exposed to the air. It was treated with nitric acid, which dissolved every thing but the manganese and iron (if any had been present.) The nitric solution, when mixed with carbonate of potash, deposited only carbonate of lime. The black residuum

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* *Ann. de Chim.* xxviii. 92.

† *Jour. de Min.* No. xix. 40.

was mixed with sugar, and treated with nitric acid. The solution was complete; therefore no iron was present.

The same processes will succeed with the other ores of manganese. When iron is present, it may be separated either as above, or by the rules laid down in the First Section of this Chapter; or we may dissolve the mixture in acetic acid, and evaporate to dryness two or three times repeatedly. The oxide of iron is left behind, while the acetate of manganese continues soluble in water.

17. *Ores of Tungsten.*

Wolfram,

1. Wolfram was analysed by the Elhuyarts, and by Vauquelin and Hecht, nearly as follows: The ore was boiled with muriatic acid, and then digested with ammonia alternately till the whole was dissolved. The ammoniacal solutions being evaporated to dryness and calcined, left the yellow oxide of tungsten in a state of purity. The muriatic solutions were mixed with sulphuric acid, evaporated to dryness, and the residuum redissolved in water. A little silica remained. Carbonate of potash precipitated a brown powder from this solution. This powder was treated with boiling nitric acid repeatedly, till the iron which it contained was oxidized to a maximum. It was then digested in acetic acid, which dissolved the manganese, and left the iron. Finally, the manganese was precipitated by an alkali.

Tungstate of lime,

Tungstate of lime was thus analysed by Klaproth. One hundred grains of it were digested in nitric acid. The yellow coloured residue was washed and digested in ammonia. The residue was digested in nitric acid and ammonia alternately till a complete solution was obtained. Two grains of silica remained behind. The nitric acid solution was mixed with ammonia, but no precipitate appeared. It was then mixed with a boiling solution of carbonate of soda. The precipitate dried weighed 33 grains. It was carbonate of lime; but when redissolved in nitric acid, it left one grain of silica. Thirty-two grains of carbonate are equivalent to 17·6 of lime. The ammoniacal solution, by evaporation, yielded small needleform crystals. When heated to redness in a platinum crucible, they left 77¼ grains of oxide of tungsten *.

18. *Ores of Molybdenum.*

Molybdena,

Molybdena may be treated with nitric acid, successively boiled upon it till it is converted into a white powder. This powder, washed and dried, is molybdic acid. The liquid obtained by washing the acid, on the addition of potash, deposites some more molybdic acid. This being separated, muriate of barytes is to be dropt into it as long as any precipitate appears. One hundred parts of this precipitate indicate 14·5 of sulphur.

19. *Ores of Uranium.*

Pechblende,

1. Pechblende, or the black ore of uranium, was dissolved by Klaproth in nitric acid. The undissolved part is a mixture of silica and sulphur. By evaporating the solution, nitrate of lead was precipitated; then nitrated uranium in crystals. The solution being now

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* *Beitrage*, iii. 45.

evaporated to dryness, and treated again with nitric acid, left the iron in the state of red oxide.

Uranitic ochre,

2. Uranitic ochre may be treated with nitric acid, which dissolves the uranium, and leaves the iron. The purity of the iron may be tried by the rules already laid down.

Green mica,

3. Green mica was dissolved by Klaproth in nitric acid, and ammonia added in excess to the solution. The oxide of uranium was precipitated; that of copper retained.

20. *Ores of Titanium.*

Menachanite,

The ores of titanium, reduced as usual to a fine powder, are to be fused with potash or its carbonate. The melted mass is then to be dissolved in hot water. A white precipitate gradually separates, which is the white oxide of titanium. This is all that is necessary to analyse the oxides; but when iron and silica are present, the following method of Chenevix may be adopted: Saturate the alkaline solution with muriatic acid. White oxide of titanium precipitates. Separate the precipitate, and evaporate the solution to dryness. Redissolve the residuum in water. The silica remains behind. Precipitate the solution by an alkali; add the precipitate to the white oxide obtained at first, and dissolve the whole in sulphuric acid. From this solution phosphoric acid precipitates the titanium, but leaves the iron *.

The species which contains lime, and no iron, is to be fused with potash, dissolved in muriatic acid,

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* Nicholson's *Jour.* v. 132.

and the silica separated in the usual way. After this the titanium is first to be separated from the muriatic solution by ammonia; and afterwards the lime by an alkaline carbonate.

21. *Ores of Chromium.*

Chromate of lead,

1. Vauquelin analysed the chromate of lead in the following manner: When boiled with a sufficient quantity of corbonate of potash, a lively effervescence takes place; the acid combines with the potash; and carbonate of lead is formed, and remains undissolved. It may be dissolved in nitric acid, and its quantity ascertained by precipitation with sulphuric acid. Or the chromate may be treated with muriatic acid; muriate of lead precipitates, and chromic acid remains in solution. This process must be repeated till the whole of the ore is decomposed. There remains in solution chromic acid mixed with a little muriatic, which may be separated by means of oxide of silver.

Chromate of iron.

2. Tassaert analysed the chromate of iron as follows: It was melted with eight times its weight of potash in a crucible. The resulting mass dissolved in water except a brown powder. This residuum was treated with muriatic acid, which dissolved a part of it. The residuum was treated, as at first, with potash and muriatic acid, till the whole was dissolved. The alkaline solution contained the chromic acid; the muriatic solution the iron, still mixed with a little chromium. It was precipitated by potash, and the precipitate boiled with that alkali, to separate the whole of the chromic acid. What remained was pure oxide of iron. The chromic solutions were saturated with nitric acid, and mixed with nitrate of lead. The resulting precipitate indicated the

proportion of chromic acid ; for 100 parts of chromate of lead indicate about 35 of chromic acid.

SECT. IV.

METHOD OF OBTAINING PURE METALS.

THE method of analysing the different ores with precision being ascertained, we have it in our power to obtain the metals in a state of purity, which is often necessary for chemical purposes. In this Section I shall give a short view of the processes commonly employed for that purpose.

1. *Gold.* To obtain pure gold, we have only to dissolve the gold of commerce in nitro-muriatic acid, and precipitate the metal by dropping in a solution of sulphate of iron, the powder which precipitates, after being well washed and dried, is pure gold.

2. *Platinum.* Platinum can scarcely be obtained perfectly pure in the malleable state, at least in any considerable quantity ; because a sufficient heat for melting it cannot be obtained. But its powder may be procured pure from the muriate of platinum and ammonia, prepared by the rules laid down in the last Section. This salt is to be decomposed by heat, and the residuum, if necessary, may be redissolved in nitro-muriatic acid, and precipitated again.

Silver. Dissolve the silver of commerce in nitric acid, and precipitate with a diluted solution of sulphate of iron. The precipitate is pure silver. Or precipitate with common salt; form the precipitate into a paste with soda; put it into a crucible lined with soda, and fuse it with a brisk heat. This process gives a button of pure silver.

4. *Mercury* may be obtained pure by distilling a mixture of two parts cinnabar and one part iron-filings in an iron retort. The mercury comes over, and the sulphuret of iron remains behind; or the oxymuriate of mercury may be decomposed by ammonia, and the precipitate heated either by itself or mixed with oil.

5. *Copper* may be dissolved in muriatic acid, and the copper precipitated by a polished plate of iron; or the black oxide of copper, obtained by decomposing cuprated ammonia, may be melted with its own weight of pounded glass and pitch.

6. *Iron* can scarcely be obtained perfectly free from carbon. The processes described in a former part of this Work furnish it as pure as it can be procured.

7. *Tin* may be obtained pure by solution in strong nitric acid; the white oxide of tin is formed, which is insoluble. Let it be digested first with muriatic acid, and afterwards with aqua regia. Mix the oxide thus purified with its weight of pitch and a little borax, and melt it in a crucible.

8. *Lead* may be obtained pure from the carbonate by solution in diluted nitric acid, and precipitation by a cylinder of zinc; from the sulphuret, by solution in nitric acid, mixing the solution with muriatic acid, and crystallizing. The crystals of muriate of lead are to be dissolved in boiling water, and then evaporated to dryness. The mass is to be melted in a crucible with 2½ times its weight of black flux.

9. Chemists have hitherto failed in their attempts to obtain *nickel* in a state of absolute purity. The great difficulty is to separate it from cobalt; upon which all reagents have nearly the same action. The following ingenious method has been lately proposed by Mr Phillips: Dissolve the nickel of commerce in nitric acid to saturation. Throw down the arsenic acid by nitrate of lead. Then, after filtration, add an excess of nitric acid, and introduce an iron rod into the solution to throw down the copper. After this, precipitate the whole by carbonate of potash, and digest the precipitate in liquid ammonia. The cobalt and nickel are taken up; the iron and lead remain. Dilute the solution with water; add an excess of ammonia; then pour potash into the solution. The cobalt remains in solution, but the nickel precipitates in the state of a pure oxide, and may be reduced by exposure to a strong heat *. The process of Richter is complicated, and cannot easily be reduced to a formula.

10. *Zinc* may be dissolved in sulphuric acid, and a plate of zinc allowed to remain for a considerable time in the solution. It is then to be filtered, and the zinc to be precipitated with carbonate of soda. The precipitate, edulcorated and dried, is to be mixed with half its weight of pure charcoal, and distilled in an earthen ware retort. The zinc is found pure in the neck of the retort.

11. *Antimony* may be dissolved in nitro-muriatic acid, and precipitated by the affusion of water. The precipitate is to be mixed with twice its weight of tartar,

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* *Phil. Mag.* xvi. 312.

and fused in a crucible. A button of pure antimony is obtained.

12. *Bismuth*, if impure, may be dissolved in nitric acid, and precipitated by water. The edulcorated precipitate, formed into a paste with oil, and rapidly fused with black flux, gives a button of pure bismuth.

13. *Tellurium* was obtained pure by Klaproth, by forming its oxide into a paste with oil, and heating it to redness in a retort. The metal was rapidly revived.

14. *Arsenic*, in the state of white oxide, may be mixed with black flux and distilled.

15. *Cobalt* may be obtained pure, in all likelihood, by following the process proposed by Philips for the purification of nickel. The following is a much cheaper process recommended by Trommsdorf: Mix a pound of the best smalt with four ounces of nitre and two ounces of charcoal powder, and throw the mixture at intervals into a red hot crucible. This process is to be repeated three times. The mixture is then to be kept in a strong heat for an hour, stirred well, then mixed with four ounces of black flux, and kept in the strong heat of a forge for an hour longer. The cobalt, reduced by this treatment, is still impure. It is to be mixed again with thrice its weight of nitre, and deflagrated in a red hot crucible by small portions at a time. By this process the iron is peroxidized, and the arsenic acidified. The mass is to be well washed, and the oxide of cobalt separated by filtration. This oxide is to be dissolved in nitric acid, and evaporated to dryness. A fresh portion of acid is to be added, and the mass exposed to a moderate heat. Dilute with water, and

filter to separate the remains of the iron. Precipitate by pure potash, and reduce the oxide *.

16. *Manganese.* Digest the black oxide of manganese repeatedly in nitric acid; then mix it with sugar, and dissolve it in nitric acid. Filter the solution, precipitate by an alkali, form the white oxide thus obtained into a paste with oil, and put it into a crucible well lined with charcoal. Expose the crucible for an hour to the strongest heat of a forge.

17. *Tungsten* was obtained by Elhuyart by heating the yellow oxide violently in a crucible lined with charcoal: but this process has not succeeded with other chemists.

18. *Molybdenum* may be obtained by forming molybdic acid into a paste with oil, and heating it violently in a crucible lined with charcoal.

19. *Uranium* is procured by forming the yellow oxide of that metal into a paste with oil, drying it in a moderate heat, putting it into a crucible lined with charcoal, with a little lamp-black strewed over it. After luting on the cover, it is to be heated, at first gently, and then violently, for three quarters of an hour.

20. *Titanium*, in a very small proportion indeed, was obtained in the metallic state by mixing together 100 parts of the red oxide of the metal, 50 parts of borax, and five parts of charcoal, and forming the mixture into a paste with oil. This paste was put into a crucible lined with charcoal, and exposed for an hour and a half to the violent heat of a forge †.

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* *Jour. de Chim.* iv. 75.

† A heat of 166° W.—See Vauquelin and Hecht, *Jour. de Min.* xv. 20.

21. *Chromium* was obtained by Vauquelin in the metallic state, by putting a portion of chromic acid into a charcoal crucible, inclosed in a common crucible lined with charcoal, and exposing it for an hour to the violent heat of a forge.

BOOK IV.

OF

VEGETABLES.

Book IV.

VEGETABLES are too well known to require any definition. They are perhaps the most numerous class of bodies belonging to this globe of ours; the species already known amounting to no less than 30,000, and very considerable additions are daily making to the number. But it is not my intention in this place either to enumerate, to describe, or to classify plants. These tasks belong to the botanist, and have been successfully accomplished by the zeal, the singular address, and the indefatigable labour, of Linnæus and his followers.

It is the business of the chemist to analyse vegetables, to discover the substances of which they are composed, to examine the nature of these substances, to investigate the manner in which they are combined, to detect the processes by which they are formed, and to ascertain the chemical changes to which plants, after they have ceased to vegetate, are subject. Hence a chemical investigation of plants comprehends under it four particulars: 1. An account of the different *substances* found in the vegetable kingdom. 2. An account of the composition and properties of the different *parts* of vegetables ; as the leaves, the bark, the seed, &c. These must be composed of combinations of the various substances described under the first head. 3. An account of the *vegetation* of plants, as far as it can be illustrated by chemistry. 4. An account of the *changes* which plants undergo after they cease to vegetate. These different heads shall form the subject of the four following Chapters.

CHAP. I.

OF THE INGREDIENTS OF PLANTS.

The substances hitherto found in the vegetable kingdom, all of them at least which have been examined with any degree of accuracy, may be reduced under four heads: I. Substances soluble in water, at least in some state or other, and which in general are solid, and not remarkably combustible. II. Substances either fluid or which melt when heated, and burn like oils. They are all insoluble in water, but in general they dissolve in alcohol. III. Substances neither soluble in water nor alcohol, nor ether, and which have a fibrous or woody texture. IV. Substances which belong to the mineral kingdom, which occur only in small quantity in vegetables, and may therefore be considered as extraneous or foreign. The following Table exhibits a view of the different vegetable substances hitherto discovered, arranged under their respective heads.

I. 1. Acids
2. Sugar
3. Sarcocoll
4. Asparagin
5. Gum
6. Mucus
7. Jelly
8. Ulmin

9. Inulin
10. Starch
11. Indigo
12. Gluten
13. Albumen
14. Fibrin
15. Bitter principle
16. Extractive
17. Tannin
18. Narcotic principle

II. *Oleoform*
  1. Fixed oil
  2. Wax
  3. Volatile oil
  4. Camphor
  5. Bird-lime
  6. Resins
  7. Guaiacum
  8. Balsams
  9. Gum resins
  10. Caoutchouc

III. *Fibrous*
  1. Cotton
  2. Suber
  3. Wood

IV. *Extraneous*
  1. Alkalies
  2. Earths
  3. Metals.

The properties of these different substances form the subject of the following Sections.

SECT. I.

OF ACIDS.

The acids found ready formed in vegetables are the following:

Acids contained in plants.

1. Acetic
2. Oxalic
3. Tartaric
4. Citric
5. Malic
6. Gallic
7. Benzoic
8. Prussic
9. Phosphoric.

Sometimes also the sulphuric, nitric, and muriatic acids occur in vegetables, combined with alkalies or earths, but never except in very minute quantities.

Acetic.

1. Acetic acid is easily detected by its peculiar odour, and by the compounds which it forms with the alkalies and earths. It has been found by Vauquelin in the sap of different trees which he examined, and likewise in the acid juice of the *cicer arietinum*, which consists of oxalic acid, malic acid, and a little acetic *. Scheele obtained it from the *sambucus nigra* †.

Oxalic.

2. Oxalic acid is easily detected and distinguished by the following properties: It decomposes all calcareous salts, and forms with lime a salt insoluble in water. It readily crystallizes. Its crystals are quadrilateral prisms. It is totally destroyed by heat.

Plants containing it.

Oxalic acid was first detected in vegetables by Scheele. It exists in the state of superoxalate of potash in the leaves of the *oxalis acetosella*, *oxalis corniculata*, and different species of *rumex*; and likewise in the *geranium acidum*. In the root of *rhubarb* Scheele found it in the state of oxalate of lime; and Deyeux, Dispan, and Vauquelin, have observed it uncombined in the liquid which exudes from the *cicer parietinum*. Scheele detected the presence of oxalate of lime in a variety of roots and barks besides rhubarb. He reduced the substances to be examined to powder or thin slices, digested them for two hours in diluted muriatic acid, and dropt ammonia in excess into the filtered solution. If the oxalate was present, the liquid became gradually

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* *Jour. de Phys.* lii. 362.

† *Ann. de Chim.* vi. 13.

milky, and deposited it. The following is his Table of the roots and barks from which he obtained this salt *:

I. Roots.

- Alkanna
- Apium
- Bistorta
- Carlina acaulis
- Curcuma
- Dictamnus albus
- Fæniculum
- Gentiana rubra
- Vincetoxicum
- Lapathum
- Liquiritia
- Mandragora
- Ononis
- Iris florentina
- Iris nostras
- Saponaria
- Scilla
- Sigellum salomonis
- Tormentilla
- Valeriana
- Zedoaria
- Zengiber.

II. Barks.

- Berberis
- Cassia fistularis
- Canella alba
- Cinnamomum
- Cascarilla
- Cassia caryophyllata
- China
- Culilavan
- Frangula
- Fraxinus
- Quassia
- Quercus
- Simaruba
- Lignum sanctum
- Ulmus.

Tartaric.

3. Tartaric acid is known by the following properties: When a little potash is cautiously dropt into a solution containing it, common tartar is formed, and precipitates to the bottom. Tartaric acid does not decompose the sulphate, nitrate, or muriate of lime. Tartrate of lime is insoluble in water. Tartaric acid crystallizes. Its crystals are long slender prisms. It is destroyed by heat.

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* Crell's *Annals*, iii. 2. English Transl.

Chap. I.

Plants containing it.

Tartaric acid has been found in the following vegetable substances:

The pulp of the tamarind *.
The juice of grapes.
Mulberries †.
Rumex acetosa, *sorrel* †.
Rhus coriaria, *sumach* ‡.
Rheum rhaponticum §.
Agave Americana ||.
The roots of triticum ripens †.
Leontodon taraxicum †.

In the greater number of these it is in the state of supertartrate of potash.

Citric.

4. Citric acid is distinguished by the following properties: It does not form tartar when potash is added to it. With lime it forms a salt insoluble in water, which is decomposed by sulphuric, nitric, and muriatic acids. It readily crystallizes. It is destroyed by heat.

Plants containing it.

Citric acid has been found unmixed with other acids in the following vegetable substances ¶:

The juice of oranges and lemons.
The berries of vaccinium oxycoccos, *cranberry*.
——— vitis idæa, *red whortleberry*.
Prunus padus, *birdcherry*.
Solanum dulcamara, *nightshade*.
Rosa canina, *hip*.

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[*] Vauquelin, *Ann. de Chim.* v. 92.

[†] Hermbstadt on *Veget. Acids*.

[‡] Gren and Trommsdorf.

[§] Bindheim, Crell, 1788, St. 7. s. 42.

[||] Hoffman of Weimar.

[¶] Scheele, Crell's *Jour.* ii. 8. Eng. Transl.

It occurs mixed with other acids in many other fruits. Citrate of lime exists also in the onion.

Malic.

5. Malic acid is known by the following properties: It forms with lime a salt soluble in water, which is decomposed by citric acid. It does not form tartar with potash. It is incrystallizable. Heat destroys it.

Plants containing it.

Malic acid has been found by Scheele * in the fruits of the following plants, which contain no other acid:

Apples.
Berberis vulgaris, *barberry*.
Prunus domestica, *plum*.
——— spinosa, *sloe*.
Sambucus nigra, *elder*.
Sorbus aucuparia, *roan* or *service*.

Plants containing citric and malic acids.

In the following fruits he found nearly an equal quantity of malic and citric acids †:

Ribes grossularia, *gooseberry*.
—— rubrum, *currants*.
Vaccinium myrtillus, *bleaberry*.
Crategus aria, *beam*.
Prunus cerasus, *cherry*.
Fragaria vesca, *strawberry*.
Rubus chamæmorus, *cloudberries*, *evrochs*.
—— idæus, *raspberry*.

Malic acid has also been found in the agave americana ‡, and in the pulp of tamarinds §. In the first of these it is mixed with tartaric acid; in the second with

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* Scheele, Crell's *Jour.* ii. 8. Eng. Transl.

† Ibid.

‡ Hoffman of Weimar.

§ Vauquelin, *Ann. de Chim.* v. 92.

tartaric and citric acids. Vauquelin has lately detected it in the state of malate of lime, in the following plants:

Sempervivum tectorum.
Sedum album, acre, telephium.
Arum maculatum.
Different species of crassula and mesembrianthemum[*].

Gallic.

6. Gallic acid is known by the following properties: With the red oxide of iron it produces a black colour. It is crystallizable. Heat destroys it. It has been found in a great number of plants, chiefly in the bark. The following Table, drawn up by Mr Biggin[†], will serve to show the relative proportions of this acid in different plants:

Plants containing it.

Elm	7	Sallow	8
Oak cut in winter	8	Mountain ash	8
Horse chesnut	6	Poplar	8
Beech	7	Hazel	9
Willow (boughs)	8	Ash	10
Elder	4	Spanish chesnut	10
Plum tree	8	Smooth oak	10
Willow (trunk)	9	Oak cut in spring	10
Sycamore	6	Huntingdon or Leicester willow	10
Birch	4		
Cherry tree	8	Sumach	14

Benzoic.

7. Benzoic acid is distinguished by its aromatic odour, and its volatility on the application of a very moderate heat. It has been found hitherto only in a few vege-

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[*] Vauquelin, *Ann. de Chim.* xxxv. 153.

[†] Nicolson's *Journal*, iii. 394.

table substances, to which the French chemists have confined the term *balsam*. These are, *benzoin*, *balsam of tolu*, *storax*, &c.

Prussic.

8. The smell and the property of forming Prussian blue with the oxygenized salts of iron are sufficient to characterize the prussic acid. Ever since Scheele pointed out the method of procuring this acid in a separate state, the similarity between its smell and the odour of bitter almonds, peach blossoms, and other vegetable substances, did not fail to be remarked : But it was not till about the year 1802 that Bohn observed a similarity between the taste of prussic acid and the water distilled from bitter almonds ; and that when this water was mixed with potash, it acquired the property of precipitating iron solutions blue. These results were confirmed soon after by Schræder, who succeeded also in obtaining prussian blue, by the same means, from the distilled waters of *laurocerasus* leaves and peach blossoms. When lime is added to the concentrated waters of these substances, there is formed a prussiate of lime ; for when the liquid is mixed with a salt of iron, prussian blue precipitates the instant that another acid is added. When these waters are distilled off pure potash, a prussiate of potash remains, and even crystallizes. The water that comes over contains no prussic acid. When distilled with ammonia, no prussian ley is obtained *.

This discovery was soon after verified by the experiments of Gehlen, Bucholz, and Vauquelin. Bucholz found that prussic acid was contained in the essential oil of bitter almonds, and that it could be separated by

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* *Jour. de Phys.* lvi. 224.

means of fixed alkalies, but not by ammonia [*]. Vauquelin obtained prussic acid by distilling water off the kernels of apricots in a water bath. The liquid, when mixed with sulphate of iron, and a little ammonia added, yields a precipitate only partially soluble in sulphuric acid. The residuum is green, but becomes blue when boiled. Hence Vauquelin supposes that the prussic acid in these bodies is in a peculiar state [†]. Schræder has since obtained prussic acid from the flowers of the sloe *(prunus spinosa)*, and the leaves of the bay-leaved willow (*salix pentandra*) [‡]. It cannot be doubted that almost all the bitter tasted kernels contain this acid.

Phosphoric acid.

9. Phosphoric acid is easily distinguished from the former eight; for it is very fixed, and a violent heat does not destroy it as it does the others.

Phosphoric acid has been found in different plants, but only in very small quantities: it is almost constantly combined with lime or potash, though it exists free in the onion. Meyer found it in the leaves of many trees [§]; Thuren found phosphate of lime in the *aconitus napellus* [‖]; and Bergman found it in all kinds of grain [¶]. Phosphate of potash exists in barley and other species of corn, and has, I presume, been often confounded with phosphate of lime.

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[*] Gehlen's *Jour.* i. 78.

[†] *Ann. de Chim.* xlv. 206.

[‡] Gehlen's *Jour.* i. 394.

[§] *Encyc. Meth. Phisiol. Veget.* i. 100.

[‖] *Ann. de Chim.* ii. 308.

[¶] Bergman, v. 96.

SECT. II.

OF SUGAR.

History.

SUGAR, which at present forms so important an article in our food, seems to have been known at a very early period to the inhabitants of India and China; but Europe probably owes its acquaintance with it to the conquests of Alexander the Great. The word *saccharon* occurs in Pliny[*] and Dioscorides[†]. They describe it as a white brittle solid, which exuded spontaneously from a species of reed. From the description, it does not appear that the sugar known to the ancients was similar to our sugar; but their account is so imperfect that little can be collected from it[‡]. For ages after its introduction into the West, it was used only as a medicine; but its consumption gradually increased; and during the time of the Crusades, the Venetians, who brought it from the East, and distributed it to the northern parts of Europe, carried on a lucrative commerce with sugar. It was not till after the discovery of America, and the extensive cultivation of sugar in the West Indies, that its use in Europe, as an article of food, became general[§].

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[*] Lib. xii. c. 8.

[†] *De Medica Matrice*, lib. ii. c. 104.

[‡] See Beckmann's *Historia Sacchari*. *Commentationes Soc. Reg. Gottingensis*, 1782, vol. v. p. 56.

[§] See Falconer's *Sketch of the History of Sugar*, *Manchester Memoirs*, iv. 291; and Mozeley's *History of Sugar*.

Sugar was formerly manufactured in the southern parts of Europe ; but at present almost the whole of our sugar is produced in the East and West Indies. The plant from which it is procured is the *arundo saccharifera* or *sugar cane*. Other plants indeed contain it ; but not in such abundance. In North America, however, it is extracted from the *acer saccharinum* or sugar mapple, but in too small quantity for exportation. Attempts have been lately made to extract it from the beet.

Manufacture of sugar in Indostan.

1. The method of making sugar practised in Indostan is exceedingly simple, and requires little or no expensive apparatus. The soil chosen is a rich vegetable mould, in such a situation that it can be easily watered from the river. About the end of May, when the soil is reduced to the state of soft mud, either by rain or artificial watering, slips of the cane, containing one or two joints, are planted in rows about four feet from row to row, and eighteen inches asunder in the rows. When they have grown to the height of two or three inches, the earth round them is loosened. In August small trenches are cut through the field to drain off the rain, if the season prove too rainy, and to water the plants if the season prove too dry. From three to six canes spring from each slip set. When they are about three feet high, the lower leaves of each cane are carefully wrapt round it ; and then the whole belonging to each slip are tied to a strong bamboo eight or ten feet high, and stuck into the earth in the middle of them. They are cut in January and February, about nine months after the time of planting. They have now reached the height of eight or ten feet, and the naked cane is from an inch to an inch and a quarter in diameter. They

have not flowered. When this happens, the juice loses much of its sweetness. The newly cut canes are put through the rollers of a mill, and their juice collected into large iron boilers, where it is boiled down smartly to a proper consistence, the scum being carelessly taken off. The fire is then withdrawn, and the liquid by cooling becomes thick. It is then stirred about with sticks till it begins to take the form of sugar, when it is put in mats made of the leaves of the palmira tree (*borassus flabelliformis*), and the stirring continued till it is cold *. This process yields a *raw* or *powdered* sugar; but it is clammy, and apt to attract moisture from the atmosphere, because the acids in the juice have not been removed. By the addition of quicklime to the juice, in the proportion of about three spoonfuls to every 14 gallons, the sugar loses this property. The impure sugar prepared by this method is called *jagary*. Every three quarts of juice, or every six pounds, yields about one pound of sugar. From an acre of ground about 5000 pounds of sugar, and consequently about 30,000 pounds of juice, are obtained.

In the West Indies,

2. In the West India islands the raising of sugar is much more expensive, and the produce much less, owing to the high price of labour; or, which is the same thing, to the nature of the labourers, and to the inferiority of the soil. The juice extracted by passing the cane twice between iron rollers is received in a leaden bed, and thence conducted into a *receiver*. Here it cannot be allowed to stand above 20 minutes without beginning to

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* See Dr Roxburgh's Account of the Hindoo Method of cultivating the Sugar Cane, *Repertory*. ii. 425. Second Series; and Tennants's *Indian Recreations*, ii. 31.

ferment. Therefore, as soon as collected, it is run into a flat copper cauldron, called a *clarifier*, capable of holding 400 gallons or more. Here it is mixed with a quantity of lime. The maximum used is a pint of lime to every hundred gallons; but in general much less will serve. Fire is immediately applied, and the juice heated to the temperature of 140°. The fire is then extinguished. A thick viscid scum forms upon the top, which remains unbroken, and the clear liquid is drawn off from under it by a cock or syphon, and introduced into a large copper boiler. Here it is boiled briskly; the scum, as it forms, being continually removed by large scummers. When the bulk of the liquid is sufficiently diminished, it is introduced into a second boiler, and the boiling and scumming continued as before; lime-water being sometimes added if the liquid does not appear clear. From the second copper it passes into a third; and from that to a fourth, where the very same process is continued. This last copper is called the *teache*. When by continued evaporation it has become sufficiently concentrated, which is judged of by its viscidity, it is withdrawn from the fire, and introduced into the *cooler*. This is a wooden vessel about 11 inches deep, seven feet long, and from five to six wide. As it cools it crystallizes or *grains*, forming an irregular mass separated from the uncrystallized syrup or *melasses*. From the cooler it is taken and put into empty hogsheads, having holes in the bottom; through each hole the stalk of a plantain leaf is thrust, long enough to rise above the top of the hogshead. Through these holes the melasses drain into a receiver. In about three weeks the sugar becomes tolerably dry and fair, and the process is finished. The sugar in this state is sent to Britain, under the name of *muscovado* or *raw* sugar [*]. A gallon of the raw juice yields at an average about a pound of raw sugar [†].

In the French West India islands the process is somewhat different. From the cooler the inspissated juice is poured into conical shaped pots with the point undermost. As soon as it has become solid, a plug is withdrawn from the point of the cone, and the melasses suffered to drain. When no more will drop, a stratum of clay moistened with water is laid upon the top of the sugar. The water from this, slowly penetrating the sugar, carries down the remains of the melasses. Sugar treated in this way is called *clayed* sugar. The process is said to have been discovered by accident. A hen having her feet dirty had gone over a pot of sugar, and the sugar under her tread was found whiter than elsewhere. By claying, the sugar loses about one-third of its weight; but a considerable portion of the loss may be obtained by boiling down the juice that runs off. The process is not considered as so profitable in the British islands as the one which is usually followed [‡].

In North America.

3. In North America the farmers procure sugar for their own use by a still simpler process, from the sap of the *acer saccharinum* or sugar mapple tree, which abounds in the woods. It reaches maturity in about 20 years, and is then from two to three feet in diameter. In February, March, and April, the tree is bored with an auger to the depth of about $\frac{3}{4}$ inch, and in an

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[*] Edwards' *History of the West Indies*, ii. 222.

[†] Ibid. p. 224.

[‡] Ibid. ii. 232.

ascending direction. The hole is then deepened to two inches. A wooden spout is introduced into the hole to direct the flow. The sap flows from four to six weeks. When it ceases on the south side, the north side is bored. This process does not injure the tree; but on the contrary improves it. An ordinary tree yields in good seasons from twenty to thirty gallons of sap; from which are made from five to six pounds of sugar; or every forty pounds of sap yields about a pound of sugar; so that it is not one-sixth so rich as the East India sugar cane.

The sap ought never to be kept longer than twenty-four hours after it is procured from the tree. It is improved by straining through a cloth. It is put into large flat kettles, mixed usually with quicklime, white of egg, and new milk. A spoonful of slacked lime, the white of one egg, and a pint of new milk, is sufficient for fifteen gallons of sap. A little butter is added to prevent the sap from boiling over. When boiled down sufficiently, it is allowed to *grain*, or form into small crystals, which constitute raw sugar, and then purified in the usual manner *.

Refining of sugar.

4. The raw sugar imported into Europe is still farther purified. It is dissolved in water, mixed with lime, clarified by means of bullock's blood, boiled down to a proper consistency, scumming off the impurities as they rise to the top, and then poured into unglazed conical earthen vessels, where it is allowed to grain. The point of the cone is undermost, and perforated to allow the impurities to separate. The base of the cone is co-

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* See Dr Rush's Account of the Sugar Mapple Tree, *Amer. Trans* iii. 64.

vered with moist clay; the water of which gradually filters through the sugar, and displaces a quantity of impure liquid. The sugar thus purified is called *loaf sugar*. When redissolved and treated in the same way a second time, it is called *refined* sugar. This process appears to have been first practised by the Venetians.

How refined in Indostan.

5. In the East Indies, where they make very pure sugar, their process is remarkably simple and economical, but tedious. An account of this process, as practised about Aska and Barampour, has been given by Mr Anderson, surgeon of the Madras establishment. The cane juice is first strained, and then boiled with a little lime to the proper consistency for graining. It is afterwards put into small earthen pots with mouths six inches wide, and allowed to remain at least a month; sometimes six or eight months. A hole is then made in the bottom of the pots, and the liquid syrup suffered to run off from the crystallized sugar. The sugar is put upon a cloth and squeezed, being occasionally moistened with water, the better to remove the remains of the syrup. It is then dissolved in water, and boiled a second time to the proper consistency; milk and some water being added from time to time in order to clarify it, and the scum being removed as it rises. It is poured into small wide-mouthed pots, suffered to crystallize, and a hole bored in the bottom of the pots to allow the remains of the syrup to run off. To whiten the sugar, the tops of the pots are covered with the leaves of the *creeping vine;* and these are renewed every day for five or six days. When pure *sugar candy* is wanted, the sugar thus obtained is dissolved in water again, and the same process of boiling with milk and scumming is repeated. When poured

into pots, thin slices of bamboo are introduced, which prevents it from running into lumps, and induces it to form large crystals *.

Theory of sugar-making.

6. According to Dr Higgins, who went to the West Indies on purpose to examine the manufacture of sugar, the juice of the sugar cane contains a great number of bodies; but the most important of them (not reckoning sugar and water) are those which he calls *herbaceous matter* and *melasses acid*. Concerning the nature of these substances nothing very precise is known; but the great object of the manufacturer is to remove them, as they impede the crystallizing of the sugar. The *herbaceous matter* † is partly held in solution by the water, partly by the carbonic acid. When the liquid is heated to 140°, the carbonic acid is disengaged, and the herbaceous matter separates in flakes of an olive green colour. This produces the scum. Lime facilitates the separation, partly by abstracting the carbonic acid, and partly by forming an insoluble compound with the herbaceous matter. Hence its use in the first part of the process. It is called *temper* by the manufacturers. Too much is injurious in the first part of the process. It redissolves the herbaceous matter, or at least deepens the colour of the syrup ‡.

The nature of the *melasses acid* is not better known than that of the herbaceous matter; but it combines

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* *Phil. Mag.* xxi. 272.

† This is probably a different substance from any that we know at present. It seems to possess many properties in common with *gluten*. Dr Higgens says that it agrees in its properties with the dregs of refined indigo.

‡ See Higgins' Observations, *Phil. Mag.* xxiv. 308.

with the sugar, and forms an uncrystallizable syrup. Lime is necessary in the last part of the process to remove this acid; it combines with it, and the compound runs off with the syrup during the graining of the sugar *. This acid is no doubt that which exists in unripe canes, and the quantity of it of course diminishes as the cane improves in quality. I have been informed by my friend Dr Clarke of Dominica, that the quantity of lime necessary is much less when the canes are rich and ripe than when green or lodged, or when they have been cut some time before they are bruised in the mill: and that he has known the juice of rattoon rich canes boiled down into permanent crystals of sugar without the assistance of any lime. He substituted potash instead of lime; but found that the sugar obtained by this method was liable to deliquesce. Soda made the grain firmer, but smaller than usual. These facts would lead to a suspicion that the *melasses acid* is either the *acetic* or the *citric*. Dr Clarke's experiments should exclude the oxalic, tartaric, and malic acids.

These observations of Dr Clarke agree very well with the account of Dutrone, who made a very great number of experiments on sugar cane juice, and was very well acquainted with its properties. According to him it chiefly consists of sugar, extractive, and two different kinds of fecula, which are precipitated by lime. He endeavours to prove that unaltered juice contains no acid, and his experiments are sufficient to convince us, that the quantity of acid is at least very minute †.

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* See Higgins' Observations, *Phil. Mag.* xxiv. 308.

† *Histoire de la Canne.* Premiere Partie, chap. vi. and vii.

Dutrone's experiments were made before vegetable chemistry had made nearly the progress which it has now reached. Hence it is difficult, from his description, to recognise the substances which he found in sugar cane juice. But this loss has been supplied by the late experiments of Proust. Living in Spain where the sugar cane is still cultivated, he had an opportunity of examining its juice. He found it to contain gluten or green fecula, gum, extractive malic acid, sulphate of lime, and two species of sugar; namely, common sugar, and a species which is incapable of crystallizing, and can only be exhibited in the state of syrup, and which, for that reason, he calls *liquid sugar*. The quantity of acid was very minute, and probably in a warmer climate than Spain its quantity would be still smaller [*].

According to Dutrone sugar canes give about half their weight of juice, the specific gravity of which varies from 1·033 to 1·106. It is at first opaque, but when the feculent matter has precipitated, it becomes transparent, and of a green colour. When allowed to stand for some time it runs into acidity, but if the feculent matter be removed it undergoes the vinous fermentation.

Properties.

7. Sugar procured pure by the preceding methods has a very strong sweet taste, but no smell. Its colour is white; and when crystallized it is somewhat transparent. It has often a considerable degree of hardness; but it is always so brittle that it can be reduced without difficulty to a very fine powder. When two

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[*] *Ann. de Chim.* lvii. 148.

pieces of sugar are rubbed against each other in the dark, a strong phosphorescence is visible.

Sugar is not altered by exposure to the atmosphere, excepting only that in damp air it absorbs a little moisture.

Solubility in water.

8. It is exceedingly soluble in water. At the temperature of 48°, water, according to Mr Wenzel, dissolves its own weight of sugar [*]. The solvent power of water increases with its temperature; when nearly at the boiling point, it is capable of dissolving any quantity of sugar whatever. Water thus saturated with sugar is known by the name of *syrup*.

Syrup.

Syrup is thick, ropy, and very adhesive; when spread thin upon paper, it soon dries, and forms a kind of varnish, which is easily removed by water. Its specific caloric, according to the experiments of Dr Crawford, is 1·086. When syrup is sufficiently concentrated, the sugar which it contains may be obtained in crystals. The syrup is boiled down till it is thick, poured immediately into pans, and kept in a stove or room, heated so as not to be supported by animals for any length of time. The crystals concrete upon small sticks placed in the pans for that purpose [†]. The primitive form of these crystals is a four-sided prism, whose base is a rhomb, the length of which is to its breadth as 10 to 7, and whose height is a mean proportion between the length and breadth of the base. The crystals are usually four or six sided prisms, terminated by two-sided, and sometimes by three-sided summits [‡].

Crystals.

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[*] *Verwandtschaft*, p. 308.

[†] Lewis, Neuman's *Chemistry*, p. 329.

[‡] Gillot, *Ann. de Chim.* xviii. 317.

Specific gravity.

9. The specific gravity of very white sugar, according to the experiments of Fahrenheit, is 1·6065 *; according to Hassenfratz, it is only 1·4045 †.

10. Sugar, as far as is known, is not acted upon by oxygen gas. The effect of the simple combustibles on it has not been tried; but it does not appear to be great. Azotic gas nor the metals have no sensible action on it.

Action of earths on sugar.

11. The earths proper do not seem to have any action whatever on sugar; but the alkaline earths unite with it. When lime is added to a solution of sugar in water, and the mixture boiled for some time, a combination takes place. The liquid still indeed retains its sweet taste; but it has acquired also a bitter and astringent one. A little alcohol added to the solution produced a precipitate in white flakes, which appeared to be a compound of sugar and lime. Sulphuric acid precipitated the lime in the state of sulphate, and restored the original taste of the sugar. When the compound of sugar and lime was evaporated to dryness, a semitransparent tenacious syrup remained, which had a rough bitter taste, with a certain degree of sweetness ‡.

From the experiments of Mr William Ramsay, it appears that sugar facilitates and increases the solubility of lime and strontian, and forms a combination with them. But barytes seems to act with more energy, and to occasion a partial decomposition of the sugar. For on endeavouring to dissolve it in syrup it was con-

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* *Phil. Trans.* 1724, vol. xxxiii, p. 114.

† *Ann. de Chim.* xxviii. 15.

‡ Cruickshanks, Rollo on *Diabetes*, p. 460.

stantly converted into a carbonate, and very little in consequence dissolved *.

Of alkalies,

12. The fixed alkalies combine with sugar, and form compounds not unlike that which has been just described. Potash destroys the sweet taste of syrup more completely than lime; but when it is neutralized by sulphuric acid, and the sulphate precipitated by alcohol, the sweet taste is completely restored. When alcohol is agitated with the compound of sugar and potash dissolved in water, it refuses to unite with it, but swims on the top in a state of purity †.

Of acids,

13. The acids are capable of dissolving sugar, and those which are concentrated decompose it. Sulphuric acid very soon acts upon it; water is formed, and perhaps also acetic acid; while charcoal is evolved in great abundance, and gives the mixture a black colour, and a considerable degree of consistency. The charcoal may be easily separated by dilution and filtration. When heat is applied, the sulphuric acid is rapidly converted into sulphurous acid.

Nitric acid dissolves it with an effervescence, occasioned by the evolution of nitrous gas, and converts it into malic and oxalic acids. 480 grains of sugar, treated with six ounces of nitric acid, diluted with its own weight of water, and cautiously heated, separating the crystals as they formed, yielded 280 grains of oxalic acid. So that 100 parts of sugar yield by this treatment 58 parts of oxalic acid ‡. When liquid oxymuriatic acid is poured upon sugar in powder, it is dissol-

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* Nicholson's *Jour.* xviii. 9.

† Cruickshanks, Rollo on *Diabetes*, p. 460.

‡ Ibid.

ved, and immediately converted into malic acid; and the oxymuriatic acid is converted into common muriatic acid [*].

Sugar absorbs muriatic acid gas slowly, and assumes a brown colour and very strong smell [†]. The vegetable acids dissolve it; but seemingly without producing any alteration on it.

Of alcohol,

14. Sugar is soluble in alcohol, but not in so large a proportion as in water. According to Wenzel, four parts of boiling alcohol dissolve one of sugar [‡]. But this proportion is surely too great. Lewis could only dissolve one part of sugar in 12 of boiling rectified spirits, and Margraf in 16 parts. When the solution is set aside for a few days, the sugar separates in elegant crystals [§]. Sugar unites readily with oils, and renders them miscible with water. A moderate quantity of it prevents, or at least retards, the coagulation of milk; but Scheele discovered that a very large quantity of sugar causes milk to coagulate [||].

Of sulphurets, &c.

15. The hydrosulphurets, sulphurets, and phosphurets of alkalies and alkaline earths, seem to have the property of decomposing sugar, and of bringing it to a state not very different from that of gum. Mr Cruickshanks introduced a quantity of syrup into a jar standing over mercury, and then added about an equal quantity of phosphuret of lime. Phosphureted hydrogen gas was immediately extricated. In eight days the sy-

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[*] Chenevix, *Ann. de Chim.* xxviii. 193.

[†] Priestley, ii. 291.

[‡] *Verwandtschaft*, p. 305.

[§] Lewis, Neuman's *Chemistry*, p. 329.—Margraf, *Opusc.* i. 217.

[||] Scheele, ii. 32. *Dijon Trans.*

rup was withdrawn: it had lost its sweet taste, and acquired a bitter and astringent one [*]. From this solution alcohol threw down white flakes, very much resembling those of mucilage separated from water by the same liquid [†]. A little sugar was dissolved in alcohol, and phosphuret of lime added to it. No apparent action took place. The mixture, after standing in the open air for some days, was evaporated and water added. No gas was disengaged, as the phosphuret had been converted into a phosphate. The liquid being filtered and evaporated, a tenacious substance remained, much resembling gum arabic. Its taste was bitter, with a slight degree of sweetness. It did not seem soluble in alcohol. It burned like gum [‡].

Similar experiments were made by this ingenious chemist with the sulphurets. The sweet taste of the sugar was destroyed; but on account of the solubility of the different products, the nature of the change could not be ascertained.

Action of heat.

16. When heat is applied to sugar it melts, swells, becomes brownish black, emits air bubbles, and exhales a peculiar smell, known in French by the name of *caromel.* At a red heat it instantly bursts into flames with a kind of explosion. The colour of the flame is white with blue edges.

When sugar is distilled in a retort, there comes over a fluid which, at first, scarcely differs from pure water; by and bye it is mixed with what was formerly called pyromucous acid, and is now known to be a compound

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[*] This is the taste of phosphuret of lime.

[†] Rollo on *Diabetes*, p. 452.

[‡] Cruickshanks, Ibid.

of oil and acetic acid [*]; afterwards some empyreumatic oil makes its appearance, and a bulky charcoal remains in the retort. This charcoal very frequently contains lime, because lime is used in refining sugar; but if the sugar, before being submitted to distillation, be dissolved in water, and made to crystallize by evaporation in a temperature scarcely higher than that of the atmosphere, no lime whatever, nor any thing else, except pure charcoal, will be found in the retort. During the distillation, there comes over a considerable quantity of carbonic acid and carbureted hydrogen gas [†]. Sugar therefore is decomposed by the action of heat; and the following compounds are formed from it: Water, acetic acid, oil, charcoal, carbonic acid, carbureted hydrogen gas. The quantity of oil in a separate state is inconsiderable; by far the most abundant product is pyromucous acid. Sugar indeed is very readily converted into pyromucous acid; for it makes its appearance always whenever syrup is raised to the boiling temperature.

We are indebted to Mr Cruickshanks for the most precise set of experiments on the decomposition of sugar by heat. 480 grains of pure sugar were introduced into a coated retort, and heated gradually to redness.

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[*] Schrickel, in his dissertation *de salibus saccharinis*, published in 1776, endeavoured to show that pyromucous acid was a mixture of vinegar, oxalic, and tartaric acids. Fourcroy and Vauquelin have proved more lately, that it is merely acetic acid united to a little oil.

[†] Scopoli and Morveau, *Encyc. Meth. Chim.* i. 269.

The products were,

Pyromucous acid with a drop or two of oil	270 grains
Charcoal	120
Carbureted hydrogen, and carbonic acid gas	90
	480

The pyromucous acid required about 75 grains of a solution of potash to saturate it; and when thus neutralized, no ammonia was disengaged. Hence sugar contains no azote, unless we suppose a very minute portion to be present in the pyromucous acid; and even this is not likely. The charcoal burns away without leaving any residue. Hence sugar contains no earth nor fixed alkali. The proportion of the gaseous products was 119 ounce measures of carbureted hydrogen, and 41 ounce measures of carbonic acid gas [*].

Constituents.

These experiments are sufficient to show us, that sugar is composed entirely of oxygen, carbon, and hydrogen. It is of course a vegetable oxide. Lavoisier has concluded, from a series of experiments on the vinous fermentation, that these substances enter into the composition of sugar in the following proportions:

64	oxygen
28	carbon
8	hydrogen
100	

The result of a set of experiments on the action of nitric acid on sugar, gave me very nearly the same result.

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[*] Rollo on *Diabetes*, p. 452.

Sugar I found composed of

64·7 oxygen
27·5 carbon
7·8 hydrogen

100·0

Nitric acid acts upon the carbon, and converts one half of it to carbonic acid. The remainder of the sugar resolves itself into oxalic acid and water. Sugar appears from my experiments to be composed of 12 atoms; namely, 5 atoms of oxygen, 3 of carbon, and 4 of hydrogen. Its weight is 47·5 *.

Species.

17. From the experiments of different chemists, especially of Proust and Goettling, it appears that there are different species of sugar found ready prepared in the vegetable kingdom; distinguished from each other by the figure of their crystals, and other variations in their properties. The species hitherto examined are four in number; namely, common sugar, liquid sugar, sugar of grapes, and sugar of beet; and, perhaps, also manna ought to be considered as constituting a fifth species.

Common.

Common sugar is the substance which has been described in the preceding part of this Section. It is obtained from the sugar cane. As far as is known at present, there is no difference between the sugar of the maple and common sugar.

Liquid.

18. Liquid sugar was first pointed out by Proust. He has shown that it exists in a variety of fruits and vegetable juices. It is distinguished from every other species of sugar by being incapable of crystallizing.

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* *Phil. Trans.* 1807, p. 63.

It can only be exhibited in a liquid state. It is transparent and colourless when pure, and is more soluble in alcohol than common sugar. By means of that liquid it may be separated from common sugar when they happen to be mixed. It exists in the sugar cane juice, and constitutes according to Proust a considerable portion of the molasses. It exists also in grapes, peaches, apples, and other fruits *. From the experiments of Auarie it appears, that a liquid sugar may also be obtained from the stalks of the *Zea Mays*, or Indian corn ; but no method tried was capable of inducing it to crystallize †.

Sugar of grapes.

19. That grapes contain abundance of sugar has been long known. The Duc de Bullion first extracted it from the juice of grapes, and Proust pointed out the difference between it and common sugar. The juice of grapes, according to him, yielded from 30 to 40 *per cent*. of this sugar ‡. The sugar of grapes is not so white as common sugar, but it crystallizes much more readily §.

Proust has lately published a long dissertation on the properties of this sugar and the method of extracting it from grapes. It has become of great importance on the continent, on account of the difficulty of obtaining sugar from the west Indies during the war between this country and France.

Verjuice.

Verjuice, or the liquid obtained from unripe grapes

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* Proust, *Ann. de Chim.* lvii. 131.

† *Ann. de Chim.* lx. 61.

‡ *Jour. de Phys.* xxix. 5, and lvi. 113.

§ Nicholson's *Jour.* xiv. 178.

contains tartar, sulphate of potash, sulphate of lime, much citric acid, a little malic acid, extractive, and water; but neither gum nor sugar. As the grapes advance to maturity, the citric acid gradually disappears, and gum and sugar appear in its place.

Juice of ripe grapes.

The juice of ripe grapes contains also gluten and fibrous matter, merely in a state of mixture, and therefore separable by the filter, or still better by boiling and scumming the liquid. The substances held in solution are chiefly sugar, syrup, gluten, gum, and extractive. When this juice is evaporated to dryness, it yields from a third to a fifth of solid matter, according to the species of grape employed, and the season of the year.

Sugar of grapes.

To extract the sugar from this juice, Proust saturated the acids which it contains with potash, boiled it down to a half, and left it at rest. By this means several of the salts subsided. Its specific gravity was 1·215. It was then mixed with blood, heated, scummed, filtered, and boiled down to a syrup. It gradually becomes crystallized, and resembles the raw sugar from the West Indies. In this state its specific gravity is about 1·500. This raw sugar, according to Proust, is composed of

Crystallizable sugar	75·00
Syrup, or uncrystallizable sugar	24·44
Gum	0·31
Malate of lime	0·25
	100·00

Besides some extractive, the quantity of which cannot well be ascertained. The syrup holds in solution a considerable quantity, probably more than half its weight, of crystallizable sugar; but it is difficult to separate it.

The raw sugar thus obtained is not so sweet as that from the sugar cane, since four parts of the latter will go as far as five parts of the former. But it may be applied to all the purposes of common raw sugar.

This raw sugar may be refined precisely in the same way as that of the sugar-cane. It is then white, but inferior in consistence to common sugar. It is not so sweet, and has a striking resemblance to the sugar of honey. It does not crystallize, but assumes the form of sphericles. It is not so soluble as the sugar of canes, and is therefore more easily separated from the other substances in the juice of grapes.

Proust informs us that the raw sugar from grapes, when diluted sufficiently with water, ferments and is converted into wine.

Of beet.

20. Margraf discovered sugar in the roots of the *sium sisarum*, and the *beta vulgaris* and *cicla*, and pointed out a method of extracting it in the large way *. His method bears a striking resemblance to that practised in India, as described by Mr Anderson, and like it was extremely tedious. Achard has lately made several attempts to extract it in the large way from the roots of the beet. The experiments of that philosopher †, of Lampadius ‡, of the Committee appointed by the National Institute §, of Goettling ||, and of Hermbstadt ¶, have thrown more light on this interesting sub-

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* *Opusc.* i. 22.

† *Ann. de Chim.* xxxii. 163. and xxxiii. 67.

‡ Ibid. xxxviii. 76.

§ Ibid. xxxv. 134.

|| *Phil. Mag.* ix. 184.

¶ Nicolson's *Jour.* xiii. 267.

Chap. I.

ject. The method which succeeded best with Achard was, to boil the beet roots (deprived of the heart) till they became so soft as to be easily pierced by a straw. They are then cut into slices, and the juice forced out by pressure. What remains is left for twelve hours in water, and the whole subjected to the press a second time. The liquids thus obtained are filtered through flannel, boiled down to two thirds, filtered a second time, reduced by boiling to one third of the original liquid, filtered a third time, and then evaporated to the consistence of a syrup. The crystalline crust which forms on the surface is to be broken from time to time, and the spontaneous evaporation continued till the surface becomes covered with a tough coat instead of crystals. The whole is then to be thrown into woollen bags, and the mucilaginous liquid separated from the crystals by pressure. Lampadius and the French chemists think it better to employ the roots unboiled. According to Achard, sugar may by this process be obtained at the rate of about fourpence per pound. The French chemists extracted, by means of alcohol, a quantity of sugar from the beet, amounting to $\frac{1}{16}$th of its weight; but they could not procure so much by Achard's method. They calculated the expence at ninepence per pound: a price by far too high for allowing it to come in competition with common sugar. Achard has since made some alterations and improvements in his process *.

The sugar obtained by these processes has much the appearance of raw sugar; but it may be refined by the

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* See *Phil. Mag.* xxiii. 14.

common processes, and brought into the state of common sugar. From the experiments of Goettling, it appears that beet sugar is distinguished by a certain degree of a nauseous bitter taste; owing, it is supposed, to the presence of a bitter extractive matter, which Lampadius has shown to be one of the constituents of the beet.

Manna.

21. Manna was long considered as a substance which fell from the heavens, till incontestible experiments demonstrated it to be an exudation from trees. It has the form of oblong globules or masses, of a yellowish white colour, and some degree of transparency. It is the produce of various trees, but is chiefly procured from the *fraxinus ornus*, a species of ash, which grows abundantly in Sicily and Calabria. It partly exudes spontaneously during the summer months, and is partly obtained by excisions. The juice gradually concretes into a solid mass, or it is dried in the sun or in stoves *.

Pure manna is very light, and appears to consist of a congeries of fine capillary crystals. Its taste is sweet, and it leaves a nauseous impression on the tongue. It acts as a mild purgative. When dissolved in water it may be obtained again unaltered by a gentle evaporation. Alcohol dissolves it when assisted by heat; and the solution, when set aside, gradually deposites about $\frac{5}{8}$ths of the manna, in the state of a fine white light spongy crystalline mass, bearing some resemblance to camphor. This deposite has an agreeable sweet taste,

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* See Neuman's *Chemistry*, p. 325, from which all the accounts of manna to be found in chemical books have been copied.

and instantly melts upon the tongue like snow in warm water. This may be considered as pure manna. It differs from sugar in the nature of its crystals, and in its more rapid solubility. By evaporating the solution, and setting it aside repeatedly, about $\frac{7}{8}$ths more of the manna is deposited, but not so fine in colour or taste as the first precipitate. By evaporation to dryness, the remaining 8th is obtained in the state of a thick extract, which cannot easily be reduced to dryness. This may be considered as consisting chiefly of the foreign bodies to which manna owes its nauseous taste [*]. Manna differs from common sugar in several remarkable particulars. It dissolves very readily and abundantly in alcohol, and crystallizes on cooling. When digested in nitric acid it yields both oxalic and saclactic acids, whereas sugar only yields oxalic acid [†]. It does not ferment like sugar, and of course does not seem capable of furnishing alcohol [‡]. In a set of experiments on the juice of the common onion (*allium cœpe*) Fourcroy and Vauquelin found that at a temperature, between 66° and 80°, it gradually underwent the acetous fermentation without emitting any gas ; and that by this process a quantity of uncrystallizable sugar which it contained assumed most of the properties of manna. It was not precisely the same, however, with manna, for it did not yield saclactic acid when treated with nitric acid.

The common manna of the shops, according to the experiments of Fourcroy and Vauquelin, consists of four different ingredients. 1. Pure manna, which con-

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[*] Neuman, p. 326.

[†] Proust, *Annal. de Chem.* lvii. 144.

[‡] Du Puytren and Thenard, *Ann. de Chim.* lix. 51.

stitutes at least $\frac{3}{4}$ths of the whole. 2. A little common sugar, which makes it fermentable to a small extent. 3. A yellow matter with a nauseous odour, to which the purgative quality of manna seems owing. 4. A little mucilage convertable into saclactic acid. This last ingredient seems hypothetical. Several substances by fermenting seem to be converted into manna. The sugar in onion juice has been already mentioned. Fourcroy and Vauquelin found likewise that fermented melon juice contained manna, though none could be detected in it before the fermentation. Manna appears sometimes to be formed and deposited by insects *.

Plants containing sugar.

22. The plants containing sugar are very numerous. Margraf first pointed out a method of separating it from them. The plant suspected to contain it is reduced to powder or pulp, and boiled with strong alcohol. The liquid is filtered while hot, and set aside in a close vessel. In a few days the sugar separates from the alcohol and crystallizes †.

The following are the chief plants from which it has been actually extracted by chemists ‡:

The flower of the rhododendron ponticum
The sap of the acer saccharinum,
.... betula alba,
.... asclepias syriaca,
.... heraclium sphondilium,
.... cocos nucifera,
.... juglans alba,

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* See Klaproth, Gehlen's *Jour.* iv. 328.

† Margraf's *Opusc.* i. 216.

‡ See Gren's *Handbuch*, ii. 133.

The sap of the agave Americana [*],
.... fucus saccharinus,
.... ficus carica,
.... ceratonia siliqua [†],
The juice of arundo saccharifera,
.... arundo bambos [‡],
.... zea mays,
The roots of pastinaca sativa [§],
.... sium sisarum [*],
.... beta vulgaris and cicla [*],
.... daucus carota [*],
.... apium petroselinum,
The bulb of the allium cœpe.

Exudes spontaneously.

It is proper to observe, however, that from the daucus carota, Margraf could obtain only an uncrystallizable syrup. The sugar from the sap of the agave Americana bore a greater resemblance to manna than to sugar [‖]. It is very seldom that sugar exudes spontaneously from vegetables; sometimes, however, it does. Tears of a sweet substance were observed upon the ceratonia siliqua, or locust tree, some time ago in Naples. These tears were examined by Klaproth, and found to be sugar mixed with a little tannin and oxalate of potash [¶]. The inspissitated juice of the bamboo (*arundo bambos*) is known in India by the name of *sacar nambu;* a term which is supposed to be the origin of our word *sugar*, and constitutes a species of sugar celebrated as a

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[*] Margraf, *Opusc.* i. 213.

[†] Klaproth, Gehlen's *Jour.* iv. 326.

[‡] Tennant's *Indian Recreations*, ii. 288.

[§] Margraf, *Opusc.* i. 213.

[‖] Margraf, i. 241.

[¶] Gehlen's *Jour.* iv. 327.

medicine. How far it agrees with common sugar has not been ascertained.

Small crystals of sugar are found occasionally in the flower of the rhododendron ponticum. I have received some of these crystals from my friend Dr Charles Mackenzie, but too small in quantity to admit of a rigid examination. They have no regular shape ; but in other respects seem to agree with common sugar in their properties. The same sugar has been noticed by Fourcroy, Vauquelin, and Bosc *.

The list of the saccharine plants would be greatly extended were we to add all sweet-tasted fruits, such as grapes, &c. which obviously contain sugar, and some of the mushroom tribe, from which Humboldt affirms he extracted it.

Uses.

23. Sugar has now become an essential part of the food of Europeans. It contains perhaps a greater proportion of nourishment than any other vegetable substance in the same bulk. It has the advantage of most other articles of food, in not being liable to be injured by time nor by the weather. If we believe Dr Rush, the plentiful use of it is one of the best preventatives of the diseases occasioned by worms. It has been long supposed to have a tendency to injure the teeth ; but this prejudice is now given up. It has the property of preserving other vegetable substances from putrefaction ; and accordingly is often employed for that purpose, constituting the base of conserves, &c.

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* *Ann. de Chim.* lxiii. 102.

SECT. III.

OF SARCOCOLL.

THIS substance has hitherto been confounded with the gum resins, though its properties are very different. It exudes spontaneously from the *penæa sarcocolla ;* a shrub which is said by botanical writers to be indigenous in the north-eastern parts of Africa. Nothing precise is known concerning the way in which it exudes.

State.

Sarcocoll is usually sold in the state of oblong globules from the size of a pea to that of a particle of sand. Its colour is usually yellow ; and it has the semitransparency and much of the appearance of gum arabic. But some of the grains are reddish brown. Its smell is peculiar, and not unlike that of anise seed. When carefully examined, four different substances may be detected : The first, and by far the most abundant, is pure sarcocoll : The second consists of small woody fibres, and a soft yellowish white substance, not unlike the covering of the seeds of some of the cruciform plants : The third is a reddish brown substance apparently earthy : And the fourth is only detected when the sarcocoll is dissolved in water or alcohol. It then appears in soft transparent tremulous masses like jelly.

The pure sarcocoll amounts to 0·8 of the whole. When the sarcocoll is dissolved in alcohol or water, and obtained again by evaporation, it loses its smell.

It then assumes the form of semitransparent brittle brown cakes very like gum. Its specific gravity is 1·2684 *.

Properties.

This substance has a sweet taste, but leaves an impression of bitterness. In the mouth it dissolves like gum.

It is almost equally soluble in water and alcohol; the solution is yellow. The watery solution has the appearance of mucilage, and may be used for the same purposes.

Cannot be made to crystallize. When heated softens, but does not melt. It emits a slight smell of caromel. When strongly heated, it blackens, and assumes the consistence of tar, emitting a white heavy smoke having an acrid odour. In a strong fire it scarcely leaves any residuum.

These properties show us that sarcocoll is a substance intermediate between sugar and gum, partaking in some measure of the properties of each, but certainly approaching nearer to sugar than to gum. How far the combination of sugar and the bitter principle would resemble sarcocoll I have not tried.

Sarcocoll dissolves in nitric acid, and forms a solution which does not precipitate gelatine, and of course contains no tannin; but when mixed with muriate of tin or acetate of lead a precipitate falls †.

Liquorice.

Liquorice seems to approach in its nature to sarcocoll. This substance is obtained from the root of the *glycirrhiza glabra;* a plant cultivated in the south of Europe,

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* Brisson.

† Hatchett's Additional Experiments on Artificial Tannin, *Phil. Trans.* 1805.

and even in Britain. The roots are long, slender, and fibrous, of a yellow colour, and when fresh very juicy. The juice of these roots is expressed and inspissated by boiling. The substance thus obtained is *liquorice* or *black* sugar. It comes to this country from Spain in cylindrical rolls covered with bay leaves. It is afterwards purified by a subsequent process, and sold in small cylinders about the size of a goose quill, under the name of *refined liquorice*. It is of a fine black colour and glossy. It is brittle, and its fracture is glassy.

Besides the sweet matter of liquorice, there is present in it about a third part of mucilaginous matter [*], and even some charcoal. When dissolved in nitric acid, a quantity of tannin is formed, owing probably to this charcoal; for neither the saccharine nor gummy substances yield this substance to nitric acid [†]. When treated with sulphuric acid, it leaves a quantity of charcoal, amounting to $\frac{1}{4}$th of its weight. During the treatment of this substance with sulphuric acid, no tannin was evolved in Mr Hatchett's experiments [‡].

SECT. IV.

OF ASPARAGIN.

I GIVE this *temporary* name to a substance lately discovered in the juice of asparagus by Vauquelin and Ro-

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[*] Neuman, p. 425.

[†] Hatchett, Ibid.

[‡] Third Series of Experiments on Artificial Tannin, *Phil.Trans.* 1806.

Robiquet *. It was procured by the following process.

Prepa a-tion.

The juice of asparagus is expressed in the usual way, filtered, evaporated to the consistence of a syrup, and then set aside. Various crystals gradually make their appearance, and among others crystals of asparagin, easily separated from the rest on account of their colour and figure. This substance possesses the following properties :

Properties.

1. The crystals are white and transparent, and have the figure of rhomboidal prisms. The greater angle of the rhomboidal base, as ascertained by Hauy, is 130°. The edges of this base, and the two angles at the extremity of its greater diagonal, are truncated.

2. It is hard and brittle. Its taste is cool and slightly nauseous, so as to occasion a secretion of saliva.

3. It dissolves readily in hot water ; but in cold water, only sparingly. Alcohol does not dissolve it.

4. The aqueous solution does not affect vegetable blues. Neither infusion of nutgalls, acetate of lead, oxalate of ammonia, muriate of barytes, nor the hydrosulphuret of potash, occasion any change in it.

5. When triturated with potash no ammonia is disengaged. The potash appears to render it more soluble in water.

6. When heated it swells, and emits penetrating vapours, affecting the eyes and nose like the smoke of wood. It leaves a large portion of insipid charcoal, which, when incinerated, leaves scarcely a trace of residue.

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* *Ann. de Chim.* lv. 167.—Nicholson's *Jour.* xv. 242.

7. Nitric acid dissolves it with the evolution of nitrous gas. The solution has a yellow colour and a bitter taste, like that of animal substances in the same acid. Lime disengages from it a considerable quantity of ammonia.

Such are the properties of this substance ascertained by Vauquelin and Robiquet. They distinguish it sufficiently from all other vegetable substances known.

SECT. V.

OF GUM.

THERE is a thick transparent tasteless fluid which sometimes exudes from certain species of trees. It is very adhesive, and gradually hardens without losing its transparency; but easily softens again when moistened with water. This exudation is known by the name of *gum*. The gum most commonly used is that which exudes from different species of the *mimosa*, particularly the *nilotica* [*]. It is known by the name of *gum arabic*. Gum likewise exudes abundantly from the *prunus avium*, or common wild cherry tree of this country.

Properties.

Gum is usually obtained in small pieces like tears, moderately hard, and somewhat brittle while cold, so that it can be reduced by pounding to a fine powder. When pure it is colourless, but it has commonly a yellowish tinge, and it is not destitute of lustre. It has no

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[*] Schousbae, *Phil. Mag.* v. 241.

smell. Its taste is insipid. Its specific gravity varies from 1·3161 to 1·4817.

1. Gum undergoes no change from being exposed to the atmosphere; but the light of the sun makes it assume a white colour. Water dissolves it in large quantities. The solution, which is known by the name of *mucilage* *, is thick and adhesive: it is often used as a paste, and to give stiffness and lustre to linen. When spread out thin it soon dries, and has the appearance of a varnish; but it readily attracts moisture, and becomes glutinous. Water washes it away entirely. When mucilage is evaporated the gum is obtained unaltered. This mucilaginous solution may be kept for years without undergoing putrefaction. Scarcely any vegetable substance is less liable to decomposition. At last, however, the odour of acetic acid becomes perceptible in it.

Mucilage.

When gum is exposed to heat it softens and swells, but does not melt; it emits air bubbles, blackens, and

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* Hermbstadt uses this word in a different sense. He makes a distinction between *gum* and *mucilage*. The solution of *gum* in water is transparent and glutinous, and can be drawn out into threads; whereas that of *mucilage* is opaque, does not feel glutinous, but slippery, and cannot be drawn into threads. Gum may be separated from mucilage by the following process:

Let the gum, which is supposed to be mixed with mucilage, previously reduced to a dry mass, be dissolved in as small a quantity of water as possible, and into the solution drop at intervals diluted sulphuric acid. The mucilage coagulates, while the gum remains dissolved. When no more coagulation takes place, let the mixture remain at rest for some time, and the mucilage will precipitate to the bottom, and assume the consistence of jelly. Decant off the liquid part, and evaporate the mucilage to dryness by a gentle heat till it acquires the consistence of horn. *Med. and Phys. Jour.* iii. 370.

at last, when nearly reduced to charcoal, emits a low blue flame. This flame appears sooner if a flaming substance be held just above the gum. After the gum is consumed, there remains a small quantity of white ashes, composed chiefly of the carbonates of lime and potash.

2. It does not appear that gum is acted upon by oxygen gas. A solution of gum in water, when exposed to the air, soon becomes mouldy on the surface, but undergoes no farther change for a long time. The action of the simple combustibles on gum has scarcely been examined. Azotic gas seems to have no action whatever.

Action of metallic salts.

Gum does not act upon metals; but it has the property of combining with several of the metallic oxides, and forming compounds; at least some of the metallic salts occasion precipitates when dropt into solutions of gum. The most curious effect is that produced by the oxymuriate of iron. When this salt, concentrated, is dropt into a very strong mucilage, the whole becomes a brown semitransparent jelly, which is not readily dissolved by water. When dried, the jelly becomes lighter coloured, and assumes nearly the appearance of gum. Its taste is that of gum mixed with iron.

The following Table exhibits the effects of different metallic salts on the solution of gum in water, as far as my experiments go. The mucilage I used was composed of eight parts of water to one part of gum. It was transparent and quite fluid, though a little thready.

SALINE SOLUTIONS.	EFFECTS.
1. Muriate of gold	No change
2. Nitrate of silver	No precipitate nor change
3. Corrosive sublimate	No change
4. Supersulph. of mercury	No change
5. Nitrate of mercury	A white coagulum: it disappears by agitation, but returns when the solution is much diluted
5. Prussiate of mercury	Becomes slightly opal, but no precipitate
7. Nitrate of copper	No change
8. Sulphate of copper	No change
9. Muriate of copper	No change; yet the muriate is precipitated by water
10. Cuprate of ammonia	No change
11. Sulphate of iron	No change
12. Oxymuriate of iron	Little change except the mucilage be more concentrated
13. Oxynitrate of iron	No change
14. Muriate of tin	No change
15. Oxymuriate of tin	No change *
16. Smoking liquor of Libavius	No change
17. Nitrate of lead	No change
18. Acetate of lead	A copious coagulum
19. Superacetate of lead	No change

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* When the oxymuriate is approaching the gelatinous state, a flaky precipitate appears; but the same precipitate is occasioned by pure water.

SALINE SOLUTIONS.	EFFECTS.
20. Sulphate of zinc	No change
21. Nitrate of zinc	No change
22. Muriate of arsenic	No change
23. Oxide of arsenic	No change
24. Tartrate of potash and antimony	Becomes yellow, but no precipitate
25. Nitrate of bismuth	No precipitate; yet the salt is precipitated by pure water

These phenomena indicate an affinity between gum and the peroxides of mercury and iron. Copper, antimony, and bismuth, seem also to be acted on by it; for it prevents water from precipitating them in the state of subsalts.

Action of alkalies and earths.

My experiments on the action of the alkalies and earths on mucilage of the strength indicated above, are contained in the following Table:

SOLUTIONS.	EFFECTS.
Potash	No precipitate
Ammonia	No precipitate
Lime water	No precipitate
Barytes water	No precipitate
Strontian water	No precipitate
Alum	No precipitate
Sulphate of magnesia	No precipitate
Silicated potash	A white flaky precipitate, tho' very much diluted. The liquid remains transparent.
Aluminated potash	No precipitate

From this Table it appears that silica alone forms with gum an insoluble precipitate. It is by far the most delicate test of gum which I have yet met with.

Liquid potash first converts gum into a substance not unlike curd, and then dissolves it. The solution is of a light amber colour, and transparent. When long kept, the gum again falls in the state of curd. Alcohol throws down the gum in white flakes still soluble in water; but it retains the potash obstinately, and is much more friable than before. Lime water and ammonia likewise dissolve gum, and it may be afterwards separated little altered.

Of charcoal.

Charcoal powder, when mixed with a solution of gum in water, gives it a black colour, which cannot be removed by filtration, unless a very great proportion of the powder be added. In that case the water passes clear; but the whole of the gum is retained by the charcoal. Mr Lowitz found, that not less than 30 lbs. of charcoal powder must be mixed with water containing an ounce of gum dissolved in it before the water is entirely deprived of the gum *.

Of acids.

The vegetable acids dissolve gum without alteration; the strong acids decompose it.

When thrown into sulphuric acid it blackens, and soon is resolved into other substances. The charcoal formed, according to Hatchett's experiments, amounts to 0·29, and some traces of artificial tannin may also be detected †. Water and acetic acid are said likewise to be formed ‡.

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* Crell's *Annals*, ii. 167. Eng. Transl.

† Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

‡ Fourcroy, vii. 197. Engl. Transl.

When gum is dissolved in strong muriatic acid, a brown solution is obtained, which becomes perfectly transparent when diluted with water, while at the same time some charry matter falls. If the solution be now saturated with ammonia, evaporated to dryness, and the residue digested in alcohol, the alcohol assumes a deep brown colour, and dissolves the whole except a very little sal ammoniac. The gum now bears some resemblance to sugar in its properties; at least when heated it melts, and gives out a very strong smell of caromel.

Oxymuriatic acid converts gum into citric acid, according to the experiments of Vauquelin. He passed a current of oxymuriatic acid gas through a diluted solution of gum in water. In a few days almost the whole of the gum was acidified; and he detected citric acid by the formation of supercitrate of lime, soluble in water, and decomposable by oxalic acid *. If nitric acid be slightly heated upon gum till it has dissolved it, and till a little nitrous gas is exhaled, the solution on cooling deposites saclactic acid. Malic acid is formed at the same time; and if the heat be continued, the gum is at last changed into oxalic acid. Thus no less than three acids are developed by the action of nitric acid on gum †. We are indebted to Mr Cruickshanks for the most precise experiments on the quantity of oxalic acid obtainable from gum by nitric acid. By digesting 480 grains of it with six ounces of nitric acid, he obtained 210 grains of oxalic acid and six grains of oxalate of

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* *Ann. de Chim.* vi. 178.—These properties alone were not sufficient to prove the presence of citric acid, since malic acid possessed them both. Fourcroy, vii. 148.

lime[*]. No artificial tannin is formed during this process[†]. According to the experiments of Fourcroy and Vauquelin, the quantity of saclactic acid yielded by gum, when treated with nitric acid, varies from 0·14 to 0·26[‡].

Of Alcohol.

Gum is insoluble in alcohol. When alcohol is poured into mucilage, the gum immediately precipitates; because the affinity between water and alcohol is greater than that between water and gum. The gum in this case is in the state of soft opaque white flakes. Neither is gum soluble in ether. It is not soluble in oils; but when triturated with a little oil it renders the oil miscible with water.

The action of the hydrosulphurets, sulphurets, phosphurets, and of most of the salts on gum, has not been examined with any attention.

Combines with sugar.

Gum and sugar readily unite together by dissolving both in water. By gentle evaporation a perfectly transparent solid substance is obtained, which does not crystallize. When treated with alcohol it becomes white, opaque, and soft. The greater part of the sugar is dissolved, and the gum remains united to a small portion. It has a sweetish taste, and very much resembles in appearance the substance of which the nests of wasps are formed.

Destructive distillation,

3. When gum is distilled in a retort, the products are water impregnated with a considerable quantity of pyromucous acid or *acetic acid* combined with oil, a little empyreumatic oil, carbonic acid gas, and carbureted hy-

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[*] Rollo on *Diabetes*, p. 452.

[†] Hatchett, Additional Experiments on Artificial Tannin, *Phil. Trans.* 1805.

[‡] Fourcroy, vii. 199. Engl. Transl.

drogen gas. When the pyromucous acid obtained by this process is saturated with lime, a quantity of ammonia is disengaged, with which that acid had been combined. The charcoal which remained in the retort leaves behind it, after incineration, a little lime and phosphate of lime. Mr Cruickshanks, to whom we are indebted for these facts, gradually heated 480 grains of gum arabic to redness in a coated glass retort. The products were,

Pyromucous acid mixed with some oil	210 gr.
Charcoal	96
Lime and a little phosphate of lime	10
Carbureted hydrogen and carbonic acid gas	164
Total	480

The pyromucous acid liquid contained less acid than what was obtained from an equal weight of sugar in the proportion of 118 to 150. The gases consisted of 93 ounce measures of carbonic acid and 180 of carbureted hydrogen, composed of five parts charcoal to one of hydrogen. When the pyromucous acid was saturated with lime, ammonia was disengaged *.

From the experiments of Vauquelin, it appears that gum also contains traces of iron. A hundred parts of gum arabic left after incineration three parts of white ashes. These were composed chiefly of carbonate of lime; but contained also some phosphate of lime and iron, without any traces of an alkali or of sulphur. He conjectures, that in the gum the lime is usually combined with acetic acid, and perhaps sometimes with malic acid †.

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* Rollo on *Diabetes*, p. 452.

† *Ann. de Chim.* liv. 312.

Constituents.

From these experiments, it follows that gum contains oxygen, hydrogen, carbon, and azote ; besides ime and iron. The lime may be detected by dropping sulphuric acid into a solution of gum ; needleform crystals of sulphate of lime are slowly deposited *. If we compare the products obtained by the distillation of sugar with those obtained from gum, we can scarcely doubt that the latter contains the greater proportion of carbon. As it yields less pyromucous acid, it is not improbable that it contains also less oxygen. Sugar is a triple compound ; but gum contains four constituents.

Species.

4. The species of gum at present known are considerable in number ; and it is likely that a more rigid examination of the vegetable kingdom will discover a greater number. The most remarkable are, *gum arabic*, *gum senegal*, *gum tragacanth*, *gum kuteera*, *cherry-tree gum*.

Gum arabic.

Gum arabic exudes from the *mimosa nilotica*, and other species of mimosa. It is the species described in the preceding part of this Section.

Gum senegal.

5. Gum senegal, brought from the island of that name on the coast of Africa, commonly supplies the place of gum arabic in the shops, and is the sort chiefly employed by the calico-printers. It is generally in larger masses than the arabic, and its colour is darker †, but in other respects its properties are the same.

Gum tragacanth.

6. Gum tragacanth is the produce of the *astragalus tragacantha*, a thorny shrub which grows in Candia and other islands of the Levant. The gum is said to ex-

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* Cruickshanks, Rollo on *Diabetes*, p. 452.

† Lewis, Neuman's *Chem*. p. 282.

ude about the end of June from the stem and larger branches, and soon dries in the sun. It is in the state of whitish vermiform pieces, not nearly so transparent as gum arabic. From the two preceding species it differs extremely in many of its properties. When put into water it slowly imbibes a large quantity of the liquid, swells into a large volume, and formsa soft, but not fluid, mucilage. If the quantity of water be more than the gum can imbibe, the mucilage forms an irregular mass, which does not unite with the rest of the liquid. By agitation, indeed, an apparent solution is effected, and the whole assumes a wheyish appearance; but on standing, the mucilage again subsides, as at first, and the water becomes transparent *. When a solution of gum arabic is poured into this solution, the mucilaginous gum tragacanth separates much sooner than usual, and forms no union with the gum arabic †. When treated with nitric acid, it yields abundance of saclactic acid, malic acid, and oxalic acid; but not the slightest trace of artificial tannin ‡. Sulphuric acid developes some traces of artificial tannin. The quantity of charcoal which it yielded, when digested in sulphuric acid, was 0·22, or considerably less than gum arabic yielded in the same circumstances §. When Mr Cruickshanks distilled 480 grains of it in a glass retort, he obtained the following products:

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* Lewis, Neuman's *Chem.* p. 282. † Lewis, Ibid.

‡ Hatchett, *Phil. Trans.* 1805.

§ Hatchett, Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

Pyromucous acid	245 gr.
Charcoal	93
Lime with some phosphate	12
Carbonic acid and carbureted hydrogen gas	130
	480

When the pyromucous acid was saturated with lime, a considerably greater proportion of ammonia was disengaged than from the pyromucous acid of gum arabic. The gases were 78 ounce measures of carbonic acid, and 91 of carbureted hydrogen[*]. This gum yielded to Vauquelin 0·03 of ashes. They dissolved in muriatic acid with effervescence, while the odour of sulphureted hydrogen was perceptible. They consisted chiefly of carbonate of lime, with a little iron and phosphate of lime, and contained likewise some potash[†].

These experiments show us, that gum tragacanth contains more azote and lime, and perhaps more oxygen and less carbon, than gum arabic.

From the preceding account, it is obvious that tragacanth differs exceedingly from gum arabic in its properties; so much so that it ought in strict propriety to be considered as a distinct vegetable substance. The experiments of Dr Bostock render this if possible still more evident. By digesting tragacanth in water till it became gelatinous, and then triturating it with pure water in a mortar, he formed a homogeneous mucilage, consisting of 100 parts of water and one part of tragacanth. Acetate of lead formed a copious precipitate with this mucilage. The superacetate of lead produced a light precipitate, which increased by standing, though

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[*] Cruickshanks, Rollo on *Diabetes*, p. 452.

[†] *Ann de Chim.* liv. 512.

on mucilage of gum arabic it produced no effect. The oxymuriate of tin likewise throws down a firm coagulum, though it does not alter mucilage of gum arabic. Oxysulphate of iron produced no effect. Nitrate of mercury threw down a slight precipitate of a reddish tinge. Silicated potash produced no effect *.

Gum kuteera.

7. Gum kuteera is the produce of a tree which grows in Indostan; and having a considerable resemblance to gum tragacanth, great quantities were imported into this country, but did not answer as a substitute. The only account of this gum with which I am acquainted was given by Mr Cowie, in one of the volumes of the Society of Arts †. It is in loose wrinkled drops or pieces, without smell or taste, and mostly transparent. In water it slowly forms a pulp or jelly like gum tragacanth; but if pounded well in a mortar, and then boiled in water for fifteen minutes with constant agitation, it is completely dissolved. A tea spoonful of its powder gives to water the consistence of capillaire. In India it enters into the composition of some varnishes; it is used in calico-printing, and is one of the ingredients of a famous medicine for horses among them ‡.

Cherry-tree gum.

8. The prunus avium, the common cherry and plum trees, and the almond and apricot likewise, yield a gum which exudes in great abundance from natural or artificial openings in the stem §. It is of a reddish brown

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* Nicholson's *Jour.* lviii. 30. † See Nicholson's *Jour.* vii. 301.

‡ Cowie, Nicholson's *Jour.* vii. 301.

§ I stated in the last edition of this work that cherry-gum possessed the properties of gum arabic. Dr Bostock has since examined it, and found its properties different. As the specimen which I had formerly colour, in large masses, at first much softer than gum arabic, but by keeping it becomes much harder than any other species of gum which I have seen except tragacanth. When put into water it gradually swells, and is converted into a semitransparent reddish brown jelly. A portion dissolves in the water, but a considerable portion remains in the gelatinous state, and does not dissolve even though boiled for some hours in a very large portion of water. In this respect cherry-tree gum differs from every other species which I have tried. The portion dissolved in water possesses the common appearance of mucilage of gum arabic, excepting that its colour is darker, and that it is much weaker, and of course less adhesive and thready. The gum is not precipitated by alcohol, nor is any effect produced by silicated potash. Acetate of lead produces no immediate effect but; on standing the whole becomes opaque, and a precipitate at last subsides. Oxymuriate of tin causes the liquid to gelatinize immediately. The superacetate of lead, and the nitrate of mercury, produce no effect. No precipitate was produced by any of the other metallic salts tried. Dr Bostock found, that when treated with nitric acid it yielded a portion of saclactic acid. These properties, especially its incomplete solubility in water, and its not being precipitated by alcohol, show a marked difference between cherry-tree gum and gum arabic.

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examined, was obtained at second hand, and might not have been genuine, I was induced to examine gum which I had taken myself from the tree, and of the genuineness of which I was of course certain. The properties found are mentioned in the text. In general they agree with those obtained by Dr Bostock, though not in every particular.

Plants containing it.

9. It has been remarked by Mr Barrow, and probably also by others, that all the plants which yield gum have an astringent bark *. Almost all the trees known to yield gum have been enumerated in the preceding part of this Section.

Uses.

10. Gum is a very nutritive food, though seldom employed for that purpose, except when in the state of mucilage. It is used frequently as a paste, and to give stiffness or lustre to linen. The calico-printers use it in great quantities to give their colours such a degree of consistency as prevents them from running upon the cloth. It forms an ingredient in ink for a similar reason. In medicine it forms the base of many mixtures.

SECT. VI.

OF MUCUS.

The substances to which I give the name of *mucus* have been hitherto considered as varieties of gum. But the recent experiments on them by Dr Bostock, have shown that their properties differ so much from those of gum, as to entitle them to a separate place as peculiar vegetable principles. They are extremely numerous, existing in the roots, leaves, and seeds of a great

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* Travels in South Africa.

variety of plants. They seldom or never separate spontaneously, but may be obtained artificially in a state of tolerable purity. Only a few species have been hitherto examined, so that we are uncertain how far their properties agree, and only include them all under one head from analogy.

Linseed mucus.

Linseed yields one of the purest. Dr Bostock obtained it by infusing the seeds in ten times their weight of water. A fluid is obtained of the consistence of the white of an egg, which has the adhesive qualities of mucilage of gum arabic. Its taste and appearance resemble those of that liquid. When mixed with alcohol the mucus is precipitated in white flocks, but the liquid does not become opaque and milky like mucilage of gum arabic when mixed with alcohol. Acetate of lead throws down a copious dense precipitate. Superacetate of lead, and oxymuriate of tin render the liquid opaque, and also throw down a precipitate. The nitrate of mercury occasions a very slight precipitate, while muriate of gold, oxysulphate of iron, and silicated potash, produce no sensible effect whatever. No change is produced by the infusion of nutgalls *.

Other varieties.

From quince seeds, and the root of the hyacinth, Dr Bostock obtained solutions of mucus which exhibited the above properties with some shades of difference. This quince seed mucus was coagulated by acids, and by most metallic salts, and the mucus from the hyacinth was precipitated by infusion of nutgalls. These differences were probably owing to foreign bodies; such as starch, gluten, &c. with which the mucus happened

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* Bostock, Nicholson's *Jour.* xviii. 31.

to be mixed in these cases, and from which we know no method of separating it completely.

Mucus is contained in the roots and leaves of a vast number of plants. Almost all the bulbous roots and fleshy leaves yield it. For example, the roots of the *hyacinthus nonscriptus* and the *althea officinalis;* the leaves of the *althæa*, of the *malva sylvestris*, of many of the *fuci*, and of the greater number of the lichens; the seeds of flax, quinces, fenugrec, &c.

The bulbs of the hyacinth contain so much mucus, that when dried they may be employed as a substitute for gum arabic. This was first made known to the public by Mr Thomas Willis[*]. He afterwards found that the roots of the vernal squill, the white lily, comfrey, and salop, might be employed also for similar purposes[†]. A mucus may be extracted from most of the stringy lichens, which likewise answers all the purposes of a solution of gum. This was first ascertained by Georgi, who published a dissertation on the subject in the Memoirs of the Petersburgh Academy for 1779[‡]. His experiments were repeated and varied by Amoreux, who published the result of his trials in 1787[§]. Hoffman also found abundance of gum in many lichens[||]. Lord Dundonald first thought of ap-

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[*] *Phil Mag.* xv. 1803.

[†] Nicholson's *Jour.* ix. 233.

[‡] The lichens which he tried were the *farinaceus*, *glaucus*, *physodes*, and *pulmonarius.*

[§] The academy of Lyons had proposed a prize dissertation on the lichens in 1786. Three memoirs were approved of, and published by them in 1787, written respectively by Willemet, Amoreux, and Hoffman. The lichens examined by Amoreux, and found to yield a gum, were the *pulmonarius*, *prunastri*, *islandicus*, *fraxineus*, *caninus*, *coperatus*, See his Memoir, p. 95.

[||] See his Memoir, p. 23, and *passim.*

plying this discovery to practical purposes. During the last war, when the price of gum was high, lichens, at his Lordship's suggestion, were very much employed as a substitute by the calico-printers in this country.

The mucilaginous quality of the fuci is apparently still greater than that of the lichens, though the mucilage obtained from them does not answer so well.

SECT. VII.

OF JELLY.

How obtained.

If we press out the juice of ripe blackberries, currants, and many other fruits, and allow it to remain for some time in a state of rest, it partly coagulates into a tremulous soft substance, well known by the name of *jelly*. If we pour off the uncoagulated part, and wash the coagulum with a small quantity of water, we obtain *jelly* approaching to a state of purity.

Properties.

In this state it is nearly colourless, unless tinged by the peculiar colouring matter of the fruit; it has a pleasant taste and a tremulous consistency. It is scarcely soluble in cold water, but very soluble in hot water; and when the solution cools, it again coagulates into the form of a jelly*. When long boiled, it loses the property of gelatinizing by cooling, and becomes ana-

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* Vauquelin, *Ann. de Chim.* vi. 282.

logous to mucilage [*]. This is the reason that in making currant jelly, or any other jelly, when the quantity of sugar added is not sufficient to absorb all the watery parts of the fruit, and consequently it is necessary to concentrate the liquid by long boiling, the mixture often loses the property of coagulating, and the jelly of course is spoiled [†].

Jelly combines readily with alkalies; nitric acid converts it into oxalic acid, without separating any azotic gas [‡]. When dried it becomes transparent [§]. When distilled it affords a great deal of pyromucous acid, a small quantity of oil, and scarcely any ammonia [‖].

Jelly exists in all acid fruits, as oranges, lemons, gooseberries, &c. If the juices of these fruits be allowed to gelatinize, and then poured upon a searce, the acid gradually filters through, and leaves the other; which may be washed with a little cold water, and allowed to dry. Its bulk gradually diminishes, and it concretes into a hard transparent brittle mass, which possesses most of the properties of gum. Perhaps, then, jelly is merely gum combined with vegetable acid.

SECT. VIII.

OF ULMIN.

I HAVE given this temporary name to a very singular substance lately examined by Klaproth. It differs es-

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[*] Vauquelin, *Ann. de Chim.* v. 100.

[†] Id. Ibid. v. 10.

[‡] Ibid. vi. 282.

[§] Ibid. v. 100.

[‖] Ibid. vi. 286.

sentially from every other known body, and must therefore constitute a new and peculiar vegetable principle. It exuded spontaneously from the trunk of a species of elm, which Klaproth conjectures to be the *ulmus nigra*, and was sent to him from Palermo in 1802.

Properties.

1. In its external characters it resembled gum. It was solid, hard, of a black colour, and had considerable lustre. Its powder was brown. It dissolved readily in the mouth, and was insipid.

Action of water,

2. It dissolved speedily in a small quantity of water. The solution was transparent, of a blackish brown colour; and even when very much concentrated by evaporation, was not the least mucilaginous or ropy; nor did it answer as a paste. In this respect *ulmin* differs essentially from gum.

Alcohol,

3. It was completely insoluble both in alcohol and ether. When alcohol was poured into the aqueous solution, the greatest part of the ulmin precipitated in light brown flakes. The remainder was obtained by evaporation, and was not sensibly soluble in alcohol. The alcohol by this treatment acquired a sharpish taste.

Acids,

4. When a few drops of nitric acid were added to the aqueous solution, it became gelatinous, lost its blackish brown colour, and a light brown substance precipitated. The whole solution was slowly evaporated to dryness, and the reddish brown powder which remained was treated with alcohol. The alcohol assumed a golden yellow colour; and when evaporated left a light brown, bitter, and sharp resinous substance.

Changed to a resin.

5. Oxymuriatic acid produced precisely the same effects as nitric. Thus it appears that ulmin, by the addition of a little oxygen, is converted into a resinous substance. In this new state it is insoluble in water.

This property is very singular. Hitherto the volatile oils were the only substances known to assume the form of resins. That a substance soluble in water should assume the resinous form with such facility is very remarkable.

6. Ulmin when burnt emitted little smoke or flame, and left a spongy but firm charcoal, which when burnt in the open air left only a little carbonate of potash behind.

Such are the properties of this curious substance, as far as they have been examined by Klaproth *.

SECT. IX.

OF INULIN.

I HAVE given this temporary name to a new vegetable principle, lately discovered by Rose in the roots of the *inula helenium (elecampane)*.

When the roots of this vegetable are boiled in water, the decoction, after standing some hours, deposites the *inulin* in the form of a white powder like starch. Its properties are as follows:

Properties.

1. It is insoluble in cold water. By trituration the inulin is uniformly diffused, and gives the liquid a milky appearance; but it soon falls down in the state of a white powder, leaving the liquid quite transparent.

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* Gehlen's *Jour.* iv. 329.

Action of water,

2. It dissolves readily in hot water. One part of inulin in four parts of boiling water formed a solution which passed readily through the filter, though its consistence was somewhat mucilaginous, and it was not quite transparent. After some hours the greater part of the inulin precipitates from the water in the form of a white powder. An equally concentrated solution of gum arabic is much thicker, and more adhesive.

Alcohol,

3. When the aqueous solution of inulin is mixed with an equal bulk of alcohol, no change takes place for some time, but the inulin soon separates, and falls to the bottom in the state of a bulky white powder. A solution of gum arabic, when treated in this manner, remains milk white for days without any precipitate falling.

Heat,

4. When thrown upon burning coals it melts as readily as sugar, and emits a thick white smoke, not unpleasantly pungent, and similar in odour to that of burning sugar. The residue, which is but small, sinks into the coal. Starch emits a similar smoke, but leaves a more bulky residue. When heated in an iron spoon inulin melts, and emits a thick smoke, with the same odour; and as soon as the spoon becomes red hot, burns with a vivid flame, and leaves a very small coaly residue.

5. When distilled it yields a brown acid liquid, having the smell of the pyromucous acid, but not a trace of oil.

Nitric acid.

6. When treated with nitric acid it yields malic and oxalic acids, or acetic acid if too much nitric acid be employed; but no saclactic acid is formed, as happens with the gums, neither is any of the waxy matter se-

parated which is formed when starch is digested with the same acid.

Such are the properties of inulin, as far as they have been investigated by Rose *. When the root of elecampane is distilled it yields a portion of a white solid matter, which seems to be intermediate between camphor and volatile oil in its nature †. No other vegetable substance has been observed to yield a similar product. How far it is connected with inulin remains to be determined.

SECT. X.

OF STARCH.

Analysis of wheat flour.

If a quantity of wheat flour be formed into a paste, and then held under a very small stream of water, kneading continually till the water runs off from it colourless, the flour by this process is divided into two distinct constituents. A tough substance of a dirty white colour, called *gluten*, remains in the hand; the water is at first milky, but soon deposites a white powder, which is known by the name of *starch*. A sweet tasted mucilaginous substance remains dissolved in the water.

Method of making starch.

The starch obtained by this process is not altogether free from gluten; hence its colour is not very white,

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* Gehlen's *Jour.* iii. 217.

† Neuman's *Chem.* p. 420.

and it has not that fine crystallized appearance which distinguishes the starch of commerce. Manufacturers employ a more economical and more efficacious process. Good wheat is allowed to steep in cold water till it becomes soft, and yields a milky juice when squeezed. It is then taken out of the water; put into coarse linen sacks, which are subjected to pressure in a vat filled with water; a milky juice containing abundance of starch exudes, and mixes with the water of the vat. This process is repeated as long as the wheat yields any milky juice. The sack and its contents are then removed. The starch soon falls to the bottom of the vat; and the water which covers it gradually ferments, in consequence of the substances which it holds in solution. Alcohol and vinegar are formed in it, partly, no doubt at the expence of the starch. The vinegar, thus formed, dissolves all the impurities, and leaves nothing behind but starch. It is then poured off, and the starch edulcorated with water. It is afterwards dried by a moderate heat. During the drying it usually splits into small columnar masses, which have a considerable degree of regularity. The water which has stood over the starch was analysed by Vauquelin. It contains a considerable portion of alcohol and of acetic acid. The acid holds in solution gluten somewhat altered, phosphate of lime, and ammonia *.

Starch was well known to the ancients. Pliny in-

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* *Ann. de Chim.* xxxviii. 248. See *La Fabrique de l'Amidon*, by Du Hamel de Monceau. See also Gmelin's *Handbuch der Techn'schen Chemie*, ii. 737. The reader will find a description of the process followed by our manufacturers in making starch in *Phil. Mag.* xxix. 166.

forms us, that the method of obtaining it was first invented by the inhabitants of the island of Chio *.

Properties.

1. Starch has a fine white colour, and is usually concreted in longish masses ; it has scarcely any smell, and very little taste. When kept dry, it continues for a long time uninjured though exposed to the air.

Action of water,

2. Starch does not dissolve in cold water, but very soon falls to powder, and forms with it a kind of emulsion. It combines with boiling water, and forms with it a kind of jelly, which may be diffused through boiling water ; but when the mixture is allowed to stand a sufficient time, the starch slowly precipitates to the bottom. This subsidence takes place even when 90 parts of water are employed to dissolve one of starch ; but in that case, at least a month elapses before the starch begins to precipitate. This solution (if it be entitled to the name) is glutinous in proportion to the quantity of starch. If the quantity be considerable, linen dipt into it, and suddenly dried, acquires (as is well known) a great degree of stiffness. When the solution is evaporated to dryness, a brittle opaque substance is obtained, differing in appearance from common starch, but exhibiting nearly the same properties with reagents. Hence the apparent difference is probably owing to a portion of water remaining united to the boiled starch. When the solution of starch is left exposed to damp air, it soon loses its consistency, acquires an acid taste, and its surface is covered with mould.

Alcohol,

3. Starch is so far from dissolving in alcohol, even when assisted by heat, that it does not even fall to powder. Neither does starch dissolve in ether.

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* Lib. xviii. cap. 7.

4. The action of oxygen gas and of the simple combustibles and azote upon starch, has not been examined, but it is probable that it is not remarkable.

Metallic solutions;

5. The metals seem to have but little action on starch; neither does it combine with the metallic oxides; at least none of the metallic salts which I have tried, have the property of forming a precipitate when dropt into a solution of starch in water. The following were the metallic salts which I tried. The decoction used was made by boiling together one part of starch and 90 parts of water.

Nitro-muriate of gold, of platinum
Nitrate of silver, of mercury, of lead
Muriate of tin; superacetate of lead
Sulphate, muriate, and nitrate of copper
Sulphate, muriate, and nitrate of iron
Sulphate, muriate, and nitrate of zinc
Ammoniated nickel and cobalt.

Dr Bostock found that acetate of lead throws down a copious precipitate from the solution of starch in water. He obtained likewise a precipitate when oxymuriate of tin was used [*]. Hence it is obvious that his starch infusion must have contained a much greater proportion of starch than mine which formed no precipitate with muriate of tin.

Earths.

6. When lime-water is mixed with the same decoction of starch, no change is produced, neither is any perceptible alteration occasioned by strontian water;

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[*] Nicholson's *Jour.* xviii. 33.

but barytes water throws down a copious white flaky precipitate. This precipitate is redissolved by muriatic acid; but appears again on standing, unless a considerable excess of acid be employed. Yet muriate of barytes occasions no change in the decoction of starch. Silicated potash occasions no precipitate in this decoction.

Infusion of nutgalls.

7. When starch is triturated with the hot infusion of nutgalls, a complete solution is effected. This solution is transparent, and rather lighter coloured than the infusion of nutgalls. When this solution cools it becomes opaque, and a copious curdy precipitate falls. A heat of 120° redissolves this precipitate, and renders the solution transparent, but the precipitate is again deposited when the solution cools. This property I consider as characteristic of starch. The infusion of nutgalls throws it down from every solution, but the precipitate is redissolved by heating the liquid to 120° *.

Tannate of starch.

This precipitate is a compound of tannin and starch, and the constituents are capable of uniting in various proportions; but it is least soluble when deposited from the solution of 24 grains of starch in a half-ounce measure of the infusion of nutgalls, made by boiling together two parts of water and one of nutgalls. In that case it is composed of about three parts starch and two tannin. The whole of it does not precipitate; about $\frac{1}{4}$th remains in solution, seemingly containing an excess of

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* Dr Bostock refuses to admit this property of the infusion of nutgalls. Had he repeated the experiment as I have described it, or had he examined the effect of the infusion of nutgalls on worts of different kinds, he would, I have no doubt, have acceded to my opinion.

tannin. This compound of starch and tannin is of a light brownish yellow colour, semitransparent, and brittle, and has a good deal of resemblance to common sarcocoll. Its taste is astringent. It feels glutinous between the teeth like gum. In cold water it dissolves very imperfectly, but very copiously and readily in hot water. Alcohol, when digested on it, acquires a brown colour, but is incapable of separating the whole of the tannin from the starch. When this compound is heated it froths, swells, and melts, and then burns with a clear flame, leaving behind it a small portion of white ashes.

Action of potash,

8. When potash is triturated with starch, and a little water added, the whole assumes, on standing, the appearance of a semitransparent jelly. On adding water, an opal-coloured solution is obtained, from which the starch is readily thrown down by an acid. When muriatic acid is employed a peculiar aromatic odour is exhaled. When the infusion of galls is dropt into the solution of starch in potash, a yellowish white precipitate appears, but is immediately redissolved, and the liquid remains opaque, and of a dark brown colour. On adding muriatic acid a copious precipitate appears, similar to the compound of starch and tannin; but nitric acid occasions no precipitate, neither does ammonia.

The decoction of starch is neither altered by potash, carbonate of potash, nor ammonia.

Of acids.

9. When starch is thrown into any of the mineral acids, at first no apparent change is visible: But if an attempt is made to reduce the larger pieces while in acids to powder, they resist it, and feel exceedingly tough and adhesive. Sulphuric acid dissolves it slowly, and at the same time a smell of sulphurous acid is emitted; and such a quantity of charcoal is evolved, that the

vessel containing the mixture may be inverted without spilling any of it. Indeed if the quantity of starch be sufficient, the mixture becomes perfectly solid. Diluted sulphuric acid does not act sensibly on starch while cold; but when heated it dissolves it completely, apparently without decomposition, as the starch may be again thrown down by means of alcohol. Sulphurous acid has no effect upon starch.

Diluted nitric acid reduces starch to powder, and then slowly dissolves it without the assistance of heat. The acid assumes a green colour, and a small portion of white matter swims on the surface, on which the acid does not act. Alcohol throws down the starch from this solution *. Concentrated nitric acid dissolves starch pretty rapidly, assuming a green colour, and emitting nitrous gas. The solution is never complete, nor do any crystals of oxalic acid appear unless heat be applied. In this respect starch differs from sugar, which yields oxalic acid with nitric acid, even at the temperature of the atmosphere. When heat is applied to the solution of starch in nitric acid, both oxalic and malic acid are formed, but the undissolved substance still remains. When separated by filtration, and afterwards edulcorated, this substance has the appearance of a thick oil, not unlike tallow; but it dissolves readily in alcohol. When distilled it yields acetic acid, and

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* Vauquelin has lately applied this property of nitric acid to detect starch in vegetables. He digested the substance under examination in diluted nitric acid for two days, and then poured into the solution alcohol. The starch precipitated. See *Ann. de Chim.* lv. 28.

an oil having the smell and the consistence of tallow *.

Strong muriatic acid dissolves starch slowly and without effervescence. When the starch does not exceed $\frac{1}{20}$th of the acid, the solution is colourless and transparent; but if we continue to add starch, a brown colour soon appears, and the acid loses a portion of its liquidity. Its peculiar smell is destroyed, and replaced by the odour which may be perceived in corn mills.

Acetic acid does not dissolve starch. I have not tried the action of any of the other acids.

Of Alcohol,

10. Alcohol separates starch in part from its decoction. A solution of potash in alcohol occasions a copious white precipitate, which is redissolved on adding a sufficient quantity of water. A solution of sulphuret of potash in alcohol occasions a flaky precipitate in the decoction of starch. This precipitate has sometimes an orange colour.

Of heat.

11. When starch is thrown upon a hot iron, it melts, blackens, froths, swells, and burns with a bright flame like sugar, emitting at the same time a great deal of smoke; but it does not explode, nor has it the caromel smell which distinguishes burning sugar. When distilled it yields water impregnated with an acid, supposed to be the pyromucous, a little empyreumatic oil, and a great deal of carbonic acid and carbureted hydrogen gas. The charcoal which remains is easily dissipated when set on fire in the open air; a proof that it contains very little earth.

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* Scheele, Crell's *Annals*, ii. 14. English Transl.

Chap. I.

Such are the properties of wheat starch, as far as I have examined them.

Plants containing it.

12. Starch is contained in a great variety of vegetable substances; most commonly in their seeds or bulbous roots, but sometimes also in other parts. Mr Parmentier, whose experiments have greatly contributed towards an accurate knowledge of starch, has given us the following list of the plants from the roots of which it may be extracted:

Arctium lappa
Atropa belladonna
Polygonum bistorta
Bryonia alba
Colchicum autumnale
Spiræa filipendula
Ranunculus bulbosus
Scrophularia nodosa
Sambucus ebulus
——— nigra
Orchis morio
Imperatoria ostrutheum
Hyoscyamus niger
Rumex obtusifolius
——— acutus
——— acquaticus
Arum maculatum
Orchis mascula
Iris pseudacorus
—— fœtidissima
Orobus tuberosus
Bunium bulbocastanum

It is found also in the following seeds:

Oats
Rice
Maze
Millet
Chesnut
Horse-chesnut
Peas
Beans
Acorn

Indeed the greater number, if not the whole, of the vegetable seeds employed by man as an article of food, consists chiefly of starch. But that substance is always combined with some other which serves to disguise its properties; such as sugar, oil, extractive, &c. It is only by processes similar to those described in the beginning of this Section that it is extracted from these substances in a state of tolerable purity. The following substances, which may be considered as varieties of starch, deserve particular attention.

Potato starch.

1. *Potato Starch.*—When the potato is grated down to a pulp, and placed on a fine searce, if water be poured on it, a great deal of starch passes though the meshes of the searce, and may be collected in proper vessels. When washed with water and dried, it assumes a fine white colour, and possesses all the essential properties of starch. Indeed it goes much farther; a smaller quantity being sufficient to form a thick paste with water than is required of wheat starch. It has a very perceptible crystallized appearance, and is much heavier apparently than common starch. It is not likely therefore that it could be employed with the same advantage as a hair powder.

Sago.

2. *Sago.*—This substance is extracted from the pith of several species of palm in the Moluccas, Philippines, and other East Indian islands. The palm is cut into pieces of five or six feet in length; the woody part is cut off one side, exposing the pith lying, as it were, in the hollow of a canoe. Cold water is poured in, and the pith well stirred; by which means the starch is separated from the fibrous part, and passes through with the water when the whole is thrown on a searce. The sago, thus separated, is allowed to settle; the water is poured off; and when it is half dry it is granulated, by being forced through a kind of funnel. It is said to acquire its grey colour while dried in an artificial heat.

This substance is employed as an article of food, and its nourishing properties are well known *.

Salop.

3. *Salop*.—This substance comes from Persia; but is said also to be manufactured in Europe. It is supposed to be the prepared roots of different species of *orchis*, as the *morio*, *mascula*, *bifolia*, *pyramidalis*. According to Moult, the bulbous roots of these plants are deprived of their cuticle, baked in an oven for 10 or 12 minutes, which gives them their semitransparency, and then fully dried in a moderate heat †. Like sago, salop is used only as a nourishing article of food. It is said by Dr Percival to have the property of concealing the taste of salt water ‡.

Cassava.

4. *Cassava* is prepared from the roots of the *jatropha manihat*, an American plant. They are peeled and subjected to pressure in a kind of bag made of rushes. The juice that is forced out is a deadly poison, and is employed by the Indians to poison their arrows; but it deposites gradually a white starch, which when properly washed is innocent. What remains in the bag consists chiefly of the same starch. It is dried in smoke, and afterwards passed through a kind of sieve. Of this substance the cassava bread is made.

Sowans.

5. *Sowans*.—This very nutritious article of food is made in this country from the husk of oats, by a process not unlike that by which common starch is made. The husk of the oat (called *seeds*) is separated from oat-meal by the sieve. It still retains a considerable portion of farinaceous matter. It is mixed with water,

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* Forest's *Voyage*, p. 39.

† *Phil. Trans.* lix. p. 2.

‡ *Phil. Mag.* xviii. 161.

and allowed to remain for some days till the water has become sour. The whole is then thrown upon a sieve. The milky water passes through; but all the husk remains behind. The water thus obtained is loaded with starchy matter, which soon subsides to the bottom. The sour liquor is decanted off, and about an equal quantity of fresh water added. This mixture when boiled forms a very nourishing article of food; and the portion of the sour water which still adheres to the starch gives the whole a pleasant acidity.

It is curious enough that the starch-maker's water, notwithstanding the great quantity of acid which it contains, and likewise the still sourer water of sowans, are swallowed greedily by hogs. They fatten upon it.

END OF VOLUME FOURTH.

Plate IV. CHEMISTRY End of Vol. IV.