THE

PHILOSOPHICAL MAGAZINE

AND JOURNAL:

COMPREHENDING

THE VARIOUS BRANCHES OF SCIENCE,

THE LIBERAL AND FINE ARTS,

GEOLOGY,

AGRICULTURE,

MANUFACTURES AND COMMERCE.

BY ALEXANDER TILLOCH,
M.R.I.A. F.S.A. EDIN. AND PERTH, &c.

"Nec aranearum sane textus ideo melior quia ex se fila gignunt, nec noster vilior quia ex alienis libamus ut apes." JUST. LIPS. *Monit. Polit.* lib. i. cap. 1.

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If you will grant me permission, I shall continue my observations, and now only remark generally, that I believe the phænomena of electricity are produced by *one* agent susceptible of undergoing *two distinct modifications*, the one *directly opposed to the other*, each *possessing different relations to matter, from the other.*

I am, with much respect, sir,
Your obliged obedient servant,
J. MURRAY.

Witham, Essex,
January 16, 1815.

XI. *Letter from M.* AMPERE *to Count* BERTHOLLET, *on the Determination of the Proportions in which Bodies are combined, according to the respective Number and Arrangement of the Molecules of which their integrant Molecules are composed**.

YOU have been long since informed that the important discovery of M. Gay Lussac, on the simple proportions observed between the volumes of a compounded gas, and those of the component gases, gave rise to the idea of a theory which explains not only the facts discovered by this eminent chemist, and the analogous facts observed since, but which may also be applied to the determination of the proportions of a great number of other compounds, which in ordinary circumstances do not affect the gaseous state.

The memoir in which I enter upon this theory in detail, is nearly finished ; but as occupations of another description do not admit of my finishing it now, I hasten to comply with your wish of giving an abstract.

Consequences deduced from the theory of universal attraction considered as the cause of cohesion, and the facility with which the light traverses transparent bodies, have led natural philosophers to think that the latter molecules of bodies were held by the attractive and repulsive forces which are peculiar to them, at distances as it were infinitely great relative to the dimensions of those molecules.

Hence their forms, with which no direct observation can make us acquainted, have no more any influence on the phænomena presented by the bodies which are composed of them, and we must seek for the explanation of these phænomena in the manner in which these molecules arrange themselves with respect to each other, in order to form what I call a *particle*. According to this notion we ought to consider a particle as the assem-

* *Annales de Chimie*, tom. xc. p. 43.

blage

blage of a determinate number of molecules in a determinate situation, containing among them a space incomparably greater than the volume of molecules; and in order that this space may have three dimensions comparable between each other, a particle must consist of at least four molecules. In order to express the respective situation of the molecules in a particle, we must conceive by the centres of gravity of these molecules to which we may suppose them reduced, planes situated so as to leave on one and the same side all the molecules which are beyond each plane. Supposing that any molecule is not contained in the space comprized between these planes, this space will be a polyhedron, of which each molecule will occupy a summit, and it will be sufficient to name this polyhedron, in order to express the respective situation of the molecules of which a particle is composed. I shall give to this polyhedron the name of *representative form of the particle.*

Crystallized bodies being formed by the regular juxtaposition of particles, mechanical division will therein indicate planes parallel to the faces of this polyhedron; but it will be able to indicate others resulting from the various laws of decrement: besides, there is nothing to hinder the latter from being frequently more easily obtained than a part of the former; and hence mechanical division may rather furnish conjectures, and conjectures only, for the determination of the representative forms. There is another way of ascertaining these forms: *i. e.* to determine by the relation of the component parts of a body, the number of molecules in each particle of this body. For this purpose I set out on the supposition that in the case where bodies pass to the state of gas, their particles alone are separated and removed from each other by the expansive force of caloric to distances much greater than those which the forces of affinity and cohesion have an appreciable action, so that those distances depend only on the temperature and pressure which the gas supports, and at equal pressures and equal temperatures, the particles of all the gases simple or compound, are placed at the same distance from each other. The number of particles is on this supposition in proportion to the volume of the gases*. Whatever may be the theoretical reasons which seem to support it, it can only be considered as an hypothesis; but on comparing the consequences which necessarily result with the phænomena, or the properties which we observe; if it agrees with all the known results of experience, if we deduce consequences which are confirmed by ulterior experiments, it may acquire a de-

* I have learned since the drawing up of my paper, that M. Avogrado has made this last idea the groundwork of an inquiry into the proportions of the elements in chemical combinations.

gree

gree of probability which will approach to what we call in physics *certainty*. Supposing it to be admitted, it will be sufficient to know the volumes in the state of gas of a compound body and of its components, in order to know how a particle of the compounded body contains particles or portions of a particle of the two components. Nitrous gas, containing for instance the half of its volume in oxygen and the half in azote, it follows that a particle of nitrous gas is formed by the union of half a particle of oxygen and half a particle of azote; the gas formed by the combination of chlore and of the oxide of carbon, containing volumes of these two gases which are equal to its own, one of its particles is formed by the junction of a particle of chlore, and a particle of oxide of carbon; water in vapour containing, according to the fine experiments of M. Gay Lussac, an equal volume of hydrogen, and the half of its volume in oxygen, one of its particles will be composed of an entire particle of hydrogen, and the half of a particle of oxygen: for the same reason a particle of the gaseous oxide of azote will contain an entire particle of azote, and the half of a particle of oxygen: finally, a volume of ammoniacal gas being composed of a half volume of azote, and a volume and a half of hydrogen, a particle of this gas will contain the half of a particle of azote, and a particle and a half of hydrogen.

If we admit as the most simple supposition, (a supposition which appears to me sufficiently justified by the harmony of the consequences which I have deduced from it, with the phænomena) that the particles of oxygen, of azote, and of hydrogen are composed of four molecules; we shall conclude, that those of the nitrous gas are also compounded of four molecules, two of oxygen and two of azote; those of the gaseous oxide of azote of six molecules, four of azote and two of oxygen; those of the vapour of water of six molecules, four of hydrogen and two of oxygen; and those of ammoniacal gas of eight molecules, six of hydrogen, and two of azote.

The supposition that the particles of *chlore* are also compounded of four molecules, cannot agree with the phænomena presented by this gas in its various combinations: we are necessarily led to account for these phænomena, to admit eight molecules in each of its particles, and to suppose either that these molecules are of the same nature, or that the particles of chlore contain four molecules of oxygen, and four molecules of an unknown combustible body.

The first hypothesis simplifies so much the explanations which are about to follow, that it would be a sufficient reason to use it for that purpose alone, even if we did not regard it as the most probable. [To be continued.]

XII. *Ob-*

Pond *Muscles* but much smaller? and to which particular stratum or strata in Mr. Forster's Section, they belong.

In the same work I observe it mentioned, that Professor Hailstone, of Cambridge, has presented to the Geological Society an account of Fossils found near that place, partly in a bed of calcareous blue clay, called *Galt*, which he considers as the lowest bed of the Chalk formation, and which therefore should seem to be the *Chalk Marl* of several modern writers; whereas *Galt* is more commonly applied to *alluvial Clay*, in the district alluded to. I wish therefore to inquire of Mr. H. or any other of your readers, whether some of the extraneous fossils there mentioned, such as charred wood, mutilated Fish, Pentacrinites, &c. were not found in moved and water-worn *alluvial Clay*, instead of their being imbedded in stratified *Chalk Marl?*

I am, &c.

Feb. 2, 1815. A CONSTANT READER.

XX. *Letter from M.* AMPERE *to Count* BERTHOLLET, *on the Determination of the Proportions in which Bodies are combined, according to the respective Number and Arrangement of the Particles of which their integrant Molecules are composed.*

[Continued from p. 43.]

If we now proceed to consider the primitive forms of the crystals recognised by mineralogists, and regard them as the representative forms of the most simple particles, admitting into these particles as many molecules as the corresponding forms have summits, we shall find that they are five in number; the tetrahedron, the octahedron, the parallelopipedon, the hexahedral prism, and the rhomboidal dodecahedron.

The particles corresponding to these representative forms are composed of 4, 6, 8, 12 and 14 molecules; the three first of these numbers are those which we require to explain the formation of the gases to be immediately cited. I have shown in my memoir that the number 12 is that which we must employ in order to express the composition of the particles of several very remarkable combinations, and that number 14 accounts for that of the particles of the nitric acid, as it will be if we can obtain it without water, for that of the particles of the muriate of ammonia, &c.

Let us now see how the molecules may be united according to these different forms:

Two molecules being supposed to be united on a line, to give a clearer idea of their respective position; if we add thereto two

two other molecules united in the same manner, at first in one and the same plan, so that the two lines mutually cut each other into two equal parts; and if we afterwards remove them, by keeping them always in a situation parallel to that which they had on this plan, we shall obtain a tetrahedron, which will be regular in the case only where the two lines were equally perpendicular to each other, and where they have been removed from each other to a distance, which is to their length as $1 : \sqrt{2}$.

Let us now conceive three molecules joined by lines forming any given triangle; let us place in the same plan another triangle equal to the first, and of which the situation is such that the two triangles have their centre of gravity at the same point, and their equal sides respectively parallel. Separating these two triangles, so that the three sides of each triangle may remain constantly parallel to their primitive position, we shall obtain six points placed as they ought to be to represent the six summits of an octahedron, which will be regular only in the case where we have thus joined two equilateral triangles, and where we have separated them perpendicularly to their plan from a quantity which is to one of their sides as $\sqrt{2}$ $\sqrt{3}$.

If we suppose in the case of the tetrahedron which we draw by the two lines of which we have spoken, two plans parallel between them, and we place in each of them a line which represents the position in which will be found the line of the other plan before they had been separated, the extremities of these two new lines will be the four summits of a symmetrical tetrahedron at the first, which shall have its centre of gravity at the same point, and the eight summits of those two tetrahedrons joined in this manner will be those of a parallelopipedon. It is thus that the parallelopipedon form results from the union of two tetrahedrons. It is easy to see that when the two tetrahedrons are regular the parallelopipedon becomes a cube; a rhomboidal parallelopipedon when the tetrahedrons are regular pyramids; a straight prism with rhomboidal bases when four ridges of every tetrahedron are equal to each other; and finally, the base of this prism becomes a square when to this condition is added the equality of the two other ridges. In the case of the octahedron, if we place in the same way in the plans of two triangles, of which we have spoken, those which represent the position in which will be found the triangle of the other plan before they had been separated, the six angles of these two new triangles will be the six summits of an octahedron symmetrical to the first, which shall have its centre of gravity at the same points; and the twelve summits of those two octahedrons, thus joined, will be those of a hexahedral prism: this form results, there-

fore,

fore, from the junction of two octahedrons. The hexahedral prism will not be straight, unless so far as we shall have removed the two first triangles in a direction perpendicular to their plan, and it will have for its base a regular hexagon only in the case where those two triangles are equilateral. We may remark, that in the hexahedral prism formed in this way with two regular octahedrons, the height is to the sides of the bases as $\sqrt{2} : 1$.

In general, the examination of the circumstances which result from the regularity or irregularity of the particles which are united to each other, as two tetrahedrons are in order to produce a parallelopipedon, and two octahedrons in order to give birth to a hexahedral prism, requires very complex considerations, which are of no use to the explanation of the theory which I am describing, while we are merely occupied with the number of the molecules of each particle, and cannot have an application. But when we study under this point of view the primitive forms of the crystals given by observation, I shall put them out of consideration in this extract; and as it will only be necessary to speak of the number of the molecules of which the particles formed by the union of other particles already known are composed, I shall consider as regular all the tetrahedrons and octahedrons, the various combinations of which I shall examine. It will be easy, by the help of a few reflections, to form an idea of the modifications which the results of this examination will undergo in cases where these polyhedrons are irregular.

It is evident, that by placing at the same point the centres of gravity of two tetrahedrons and an octahedron, so as that the two former should make a cube, and the situation and dimensions of the octahedron are such that the ridges of this cube and those of the octahedron mutually cut each other at right angles into two equal parts, the polyhedron with 14 summits which will result from their junction will be the dodecahedron, the last of the primitive forms given by the mechanical division of the crystals; for we ought not to reckon among these forms the double pyramid with hexagonal bases, admitted at first in order to explain the crystallization of quartz, and brought back afterwards to a parallelopipedon.

It appears from what we have said, that when particles are united into a single particle, it is by placing themselves in such a way that, the centres of gravity of the component particles being at the same points, the summits of the one are placed in the intervals left by the summits of the others, and *vice versâ*. It is in this way that I consider chemical combination; and here it differs from the aggregation of similar particles, which takes place by simple juxtaposition, as is seen in that elegant theory of crystallization which the sciences owe to M. Haüy. It is also

also in this way that I have obtained, by combining other numbers, tetrahedrons and octahedrons, the various representative forms required for the explanation upon the same principles of all the combinations in a determinate ratio which are known to me.

On attempting to join tetrahedrons and octahedrons in all possible ways, we find that there result from most of them representative forms in which the various molecules are arranged in an irregular manner, and that there are some in one direction, without there being any in another direction corresponding to the first. All these forms ought to be rejected, and we observe in fact, that the proportions which they suppose in chemical combinations are not met with in nature. If we try, for instance, to combine tetrahedrons and octahedrons, so as that the number of the former shall be the half of that of the latter, we find only awkward forms which do not present any regularity, or any proportion between the relative sizes of their different faces. Hence we ought to conclude that a body A, the particles of which have for their representative form tetrahedrons, and a body B, of which the particles are represented by octahedrons, will not unite so as that there shall be in the combination one proportion of A and two proportions of B: on the contrary, this combination will be easy between two proportions of A and one of B, since two tetrahedrons and one octahedron form by their junction a dodecahedron. In the same case, A and B will unite in equal proportions by means of two forms which I shall describe, and in which the number of the tetrahedrons is equal to that of the octahedrons.

1. An octahedron may be joined with a tetrahedron, by placing the summits of the octahedron on the prolongations of the lines which, issuing from the centre of gravity of the tetrahedron, pass by the middles of its six ridges: we thus form a polyhedron with ten summits and sixteen triangular faces, four equilateral and twelve isosceles, to which I shall give the name of hexadecahedron.

2. Two octahedrons joined in a hexahedral prism may be joined with two tetrahedrons forming a cube, in a manner analogous to that in which an octahedron is united to a cube in the dodecahedron. In order to form a clear idea of this combination, we must consider one of the diagonals of the cube as the axis of this polyhedron, and elevate for it a plan perpendicular passing by the centre of the cube. This plan will cut six of its ridges into two equal parts, the points of division being situated like the six angles of a regular hexagon, by placing thereon the middles of the six vertical ridges of a hexahedral prism formed by the junction of two regular octahedrons: the twenty

twenty summits of this polyhedron will be those of a new polyhedron which will have 30 faces; viz. six rectangular parallelograms and 24 isosceles triangles: I shall give it the name of triacontahedron.

It is easy to see from this construction that the diagonal of the cube is equal to that of the prism, and that in this way all the summits of the triacontahedron are in one and the same spherical surface.

It will be in vain to endeavour to form other combinations presenting some regularity by combining two of the foregoing polyhedrons. Let us proceed to another mode of combination. If we consider twelve points placed with regard to each other as the middles of the twelve ridges of a cube, these points will be situated by fours in three rectangular plans: hence it follows, that if we place at the first four the four angles of the square base common to the two pyramids of which one of the octohedrons is composed, to the other four the four angles of the base of a second octohedron, and to the other four those of a third octohedron, the summits of the three octohedrons will be two and two in the intersections of the three rectangular plans, and these 18 summits will be those of a polyhedron with 32 triangular faces, eight of which will be equilateral and 24 isosceles: I shall give to this polyhedron the name of trioctohedron, which refers to its generation.

The trioctohedron may, like the octohedron, be combined with two tetrahedrons forming a cube: for this purpose we shall prolong the plans of its triangular isosceles faces from the side at which they are joined with the equilateral faces until these plans meet by threes outside of the polyhedron opposite those last faces. The eight points thus determined are evidently situated with respect to each other like the eight summits of a cube: hence it follows that we might thereon place the eight summits of two tetrahedrons, the union of which with the trioctohedron will form a polyhedron with 26 summits and 24 equal quadrilateral faces. The trapezoidal form of the mineralogists is a particular case of this form, which results from a certain proportion between the axis and the sides of the square bases of the straight octohedrons, of which we may conceive the trioctohedron to be formed. I shall in general preserve the name of trapezoidal, as expressing a property always belonging to it, whatever are the dimensions of these octohedrons.

It is not with tetrahedrons as with octohedrons: we cannot unite three of them in a polyhedron which presents some regularity; but there exists one formed by the combination of four tetrahedrons. In order to obtain it, we shall consider four points situated as the four summits of a tetrahedron equal to the four which we wish to join, and we shall conceive that at each of these points is placed one of the summits of each tetrahedron; whereas the three other summits of the same tetrahedron are in the plan which passes by the three other points, and correspond to the middles of the intervals which they leave between them. I shall give to the polyhedron resulting from this combination of four tetrahedrons so united, the name of tetra-tetrahedron. This polyhedron has sixteen summits and twenty-eight triangular faces; four of which are equilateral and twenty-four isosceles.

We shall easily demonstrate, that if we prolong the plans of the twelve isosceles faces adjacent to the four equilateral faces of the side where they join to those faces, the prolongation of those plans will meet by threes outside of the tetrahedron, in four points corresponding to the middles of its four equilateral faces, and which will be the summits of a fifth tetrahedron equal to the four preceding ones: by uniting it with them, we have the twenty summits of the polyhedron which I have called penta-tetrahedron, and which has twenty-four faces; viz. twelve quadrilaterals and twelve isosceles triangles.

If we again consider twelve points situated with regard to each other as the middles of the twelve ridges of a cube, and place a tetrahedron so that, its centre of gravity being at the same point with that of the cube, two of its ridges opposite pass by four of these points; and if we do the same thing in succession with respect to five other tetrahedrons, in order that the number of the summits should be the same in all directions, we shall obtain a polyhedron with 24 summits and 14 faces, six squares, and eight hexagons, which I shall call hexa-tetrahedron.

These hexagons, all equal to each other, will have each three sides greater and three smaller, which will be to each other as $1 : \sqrt{2}-1$.

This polyhedron is evidently an octohedron only, of which the summits are truncated by plans perpendicular to its three axes: its combinations with other representative forms are more numerous than those of any of the preceding polyhedrons.

We may at first combine it with an octohedron situated in such a way that, having its centre of gravity at the same point, all the faces and all the ridges of this octohedron shall be parallel to those of the octohedron; from which we may conceive that the hexa-tetrahedron is the result of *truncatures*, by being solely subjected to the condition of its dimensions being less than those of the latter, in order that the polyhedron thus formed may

may not have re-entering angles. This polyhedron only differs from the hexa-tetrahedron in having, besides the latter, regular pyramids raised on its square faces. I shall call it a pyramidated hexa-tetrahedron.

We may also combine the hexa-tetrahedron with a cube, by uniting it to the very cube which has served for its construction. The polyhedron which results from this combination being formed by the union of a cube and a hexa-tetrahedron, I gave it the name of cube-hexa-tetrahedron; it has 32 summits and 54 faces; viz. six squares, and 48 isosceles triangles.

If we prolong in this polyhedron the plans of the twenty-four triangular faces adjacent to the square faces on the side where they join those faces, until they cut each other by fours outside of the polyhedron opposite to those squares, we shall obtain a new representative form, produced by the union of a hexa-tetrahedron, a cube, and an octohedron which will have 38 summits and 48 faces, the half of which will be equal rhombs, and the other half isosceles triangles also equal among each other. In order to designate it by a name derived from this property, which distinguishes it from all the other representative forms in which we find at once tetrahedrons and octohedrons, I shall call it amphihedron.

In order to form a simple idea of the combination of the hexa-tetrahedron with a hexahedral prism formed by the union of two regular octohedrons, we shall conceive the hexa-tetrahedron placed in such a way that two of its hexagonal faces shall be horizontal, when the middles of its six square faces will be placed as the six summits of one of the octohedrons of which the prism is composed. We may then place those six summits on the perpendiculars elevated in the midst of these faces. The six other summits of the hexahedral prism will answer to the six hexagonal faces of the hexa-tetrahedron different from those which we have placed horizontally, *i. e.* in a direction perpendicular to the axis of the prism. If we determine the respective dimensions of the two polyhedrons, so that each side of the bases of the prism shall meet the ridge of the hexa-tetrahedron, which separates those of its faces to which the two extremities of this side answer, we shall obtain a representative form composed of six tetrahedrons and two octohedrons which will have 36 summits and 50 faces; viz. two hexagons similar to those of the hexa-tetrahedron, 12 quadrilaterals, 24 isosceles triangles, and 12 scalene triangles. I shall give it the name of pentacontahedron.

In order to unite a hexa-tetrahedron with a trioctohedron, it is sufficient to place one of the three octohedrons of which the latter is composed in the same way as the octohedron which we

 have

have joined to the hexa-tetrahedron in order to change it into a pyramidated hexa-tetrahedron. The result of this combination is a polyhedron with 24 summits and 80 triangular faces. I shall give it the name of octocontahedron.

[To be continued.]

XXI. *On Fire Damps in Mines, &c.*

To Mr. Tilloch.

Sir,—I have to regret that none of the many *practical* coal masters, viewers, or agents, who are readers of your useful work, have attended to the requests that I ventured to address to them, in page 303 of your last volume, for communications on the causes and prevention of the enormous evils arising from *fire-damp* in coal mines. Since then I have read in a periodical work, to which I there alluded, a long paper by the Editor, giving a *Geognostical* Sketch of Northumberland, Durham, &c.—on which I beg to remark, that most of the facts therein mentioned, which are useful, and numerous others such, respecting the geology of this district, were already before the public, in the sections and writings of Millar, Forster, Bailey, Farey, Wynch, &c.; but of whose prior labours in the same field, not a hint escapes the learned Editor: he has however thought proper in a long *note* (written in his peculiar manner) to notice my former letter to you, referred to above; and assuming therein, without sufficient reason, that his Newcastle correspondent and myself meant to assert, that *sulphuretted* hydrogen gas occasioned the repeated explosions in Felling Colliery; proceeds to say, "Now I do not see, how *iron pyrites* can contribute to the formation of *carburetted* hydrogen;" a thing never asserted by us, but, that *probably* pyrites and *bad small coals* might *contribute* to the dangerous accumulation of inflammable gas; being well aware that a part of it, at least, issued in blowers or jets, from newly opened joints in the coal and in its roof and floor, as Mr. Buddle has so well described.

The geognostical sketch alluded to, mentions, among the late discoveries of its author in the mines of this district, that cubes of fluor spar have *been entirely removed* therefrom, without his being able to tell how or where; he says, "The change took place in the centre of the vein, a hundred fathoms below the surface of the earth, surrounded *on all sides* by walls of solid stone!, and quite impervious both to air and *moisture!*" He mentions also, icicle-like masses of *fused galena*, being found suspended in cavities in some of the veins; that in some districts (though *not in this*) a coke-like state of the coals was observed,

where

in the plans which pass by the centre of the cube, and by the three sides of this cube which form the solid angle. The thirty-two summits of the eight tetrahedrons arranged in this way will be those of a polyhedron, which, in the case where the tetrahedrons are regular and have their centre of gravity at the same point, will have eighteen faces; viz. six square and twelve hexagonal.

It is easy to see that this polyhedron is nothing but a dodecahedron, of which the six summits with four faces shall have been curtailed by one-third of the adjoining ridges; as the position of the eight tetrahedrons of which it is composed is the same for all, I have given it the name of octo-tetrahedron. The eight tetrahedrons which form this polyhedron by their junction, are placed two and two like the two tetrahedrons which form a cube, and four and four like the four tetrahedrons of which the tetra-tetrahedron is composed; we may therefore consider it also as produced by the union of four cubes, or of two tetra-tetrahedrons.

The octo-tetrahedron having six faces, the middle parts of which are situated respectively like the six summits of an octohedron, we shall be able to unite these two polyhedrons into one only, in a manner analogous to that in which the combinations hitherto described are formed: but as this polyhedron is less simple than the amphihedron, which contains precisely as many tetrahedrons and octohedrons, and which consequently necessarily leads to the same results, relative to the combinations of bodies in determinate proportions; I shall not reckon it among the representative forms.

It is evident that the octo-tetrahedron, which has eight summits situated with respect to each other like the eight summits of a cube, cannot be combined with this form; but it may, like the hexa-tetrahedron, be combined with a hexahedral prism, because it partakes with the hexa-tetrahedron of the property of having hexagonal faces. In order to form a clear idea of this combination, we may conceive a line which joins the middles of the two opposite hexagonal faces of an octo-tetrahedron, and place it in a vertical situation; we then find that those two faces are each surrounded by six other faces, viz. two square and four hexagon; and that we may place a hexagonal prism in such a way as that, the six summits of each of its bases answering to those six faces, its axis will be confounded with the line situated vertically.

The two polyhedrons thus joined give a representative form, which differs only from the octo-tetrahedron inasmuch as the twelve faces of the latter, which surround the two bases, are covered by as many pyramids, four quadrangular and eight hexagonal.

agonal. As we cannot establish between the respective dimensions of the two polyhedrons, with the view of diminishing the number of faces, any relation which is symmetrical with respect to all the similar ridges, I shall suppose that they are such that the same sphere can be circumscribed for them; and the polyhedron with forty-four summits which results from this supposition, having seventy faces, viz. four hexagon, two square, and sixty-four triangles, I shall give it the name of eptaconta-hedron.

Finally, in order to combine the octo-tetrahedron with the tri-octohedron, it is sufficient to observe that each of these polyhedrons has as many summits as the other has faces, and reciprocally; we shall soon find that the positions of these summits and of these faces are precisely such, that by placing the six summits with four faces of the tri-octohedron on the perpendiculars raised in the midst of the six square faces of the octo-tetrahedron, all the summits of each polyhedron answer to the faces of the other.

If we determine the respective dimensions of the polyhedrons, so as that the ridges of the tri-octohedron which join at the six summits just mentioned may pass by the middles of the ridges of the square faces of the octo-tetrahedron, there will result from the junction of those two representative forms a new polyhedron which will have fifty summits and seventy-two faces; viz. twenty-four quadrilateral and forty-eight isosceles triangles. This polyhedron may be considered as a tri-octohedron, of which the thirty-two faces shall have been covered by as many triangular pyramids: this is the reason why I designate it by the name of pyramidated tri-octohedron.

I shall only point out three other representative forms, composed of four, five, and seven octohedrons, and to which I have given the names of tetra-octohedron, penta-octohedron, and epta-octohedron; and for the sake of brevity, I shall not speak of the combinations which may be made of those three representative forms with the preceding polyhedrons.

If we take notice that, one octohedron being given, there are four different positions in which another octohedron of the same size forms with the first a hexahedral prism, we shall easily conceive that four octohedrons situated in those four positions will have their centre of gravity at the same point, and will form a combination into which they will all enter in the same way. This combination is the tetra-octohedron, which has twenty-four summits and fourteen faces, of which six are octagon and the eight others are equilateral triangles: by adding thereto the same octohedron which has served to determine the respective positions of the four octohedrons which we have combined, we shall have the penta-octohedron, the summits of which are thirty in in number, and which has fifty-six triangular faces, of which eight are equilateral and the other forty-eight are isosceles.

If, instead of uniting the tetra-octohedron with a single octohedron, we combine it with a tri-octohedron, by placing the six summits with four faces of the latter at the same point where we have placed the six summits of the fifth octohedron in the formation of the penta-octohedron, we shall have the polyhedron composed of seven equal octohedrons, to which I have given the name of epta-octohedron, and which has forty-two summits and eighty triangular faces, of which eight are equilateral, twenty-four isosceles, and forty-eight scalene.

I subjoin a comparative table of these twenty-three representative forms.

	Number of Tetrahedrons.	Number of Octohedrons	Number of Summits.	Number of Faces. Triangles.	Quadrilateral.	Hexagonal.	Octagonal.	Total of Faces.
Tetrahedron (1)	1	0	4	4	0	0	0	4
Octohedron	0	1	6	8	0	0	0	8
Parallelopipedon	2	0	8	0	6	0	0	6
Prism hexahedron	0	2	12	0	6	2	0	8
Dodecahedron	2	1	14	0	12	0	0	12
Hexa-decahedron	1	1	10	16	0	0	0	16
Triacontahedron	2	2	20	24	6	0	0	30
Trioctohedron	0	3	18	32	0	0	0	32
Trapezoidal	2	3	26	0	24	0	0	24
Tetra-hedron	4	0	16	28	0	0	0	28
Penta-tetrahedron	5	0	20	12	12	0	0	24
Hexa-tetrahedron	6	0	24	0	6	8	0	14
Hexa-tetrahedron pyramidated	6	1	30	24	0	8	0	32
Cubo-hexa-tetrahedron . .	8	0	32	48	6	0	0	54
Amphihedron	8	1	38	24	24	0	0	48
Pentacontahedron	6	2	36	36	12	2	0	50
Octocontahedron	6	3	42	80	0	0	0	80
Octo-tetrahedron	8	0	32	0	6	12	0	18
Eptacontahedron	8	2	44	64	2	4	0	70
Trioctohedron pyramidated .	8	3	50	48	24	0	0	72
Tetra-octohedron	0	4	24	8	0	0	6	14
Penta-octohedron	0	5	30	56	0	0	0	56
Epta-octohedron	0	7	42	80	0	0	0	80

*** Models of all these crystalline forms are executed with the greatest accuracy under the direction of Mr. J. Mawe, No. 149, Strand, where there are always to be found numerous suits of crystals cut in wood, agreeably to Haüy's system of crystallography. These models, and the small specimens in cabinets containing from 100 to 1000 and upwards different minerals, which are sold by Mr. Mawe on very reasonable terms, accompanied with descriptive catalogues, certainly present the easiest and best means of acquiring a knowledge of the sciences of crystallography and mineralogy, and are well worthy the attention not merely of young students, but even of more experienced persons, in these somewhat difficult and apparently arduous but pleasing studies.

It is by these polyhedrons that I have represented the various arrangements of the molecules of all bodies. When these bodies contain such substances only of which we may measure the volume in the state of gas, we have immediately the number of the molecules of each species which enter into their composition. When a simple body cannot be obtained in the state of gas, we must try in succession various suppositions relative to the number of molecules of this simple body, which are contained in one of the compounds which it forms with a gaseous substance, oxygen for instance. The relations in weight make known the number of the molecules of the same body which enter into its other compounds; and the condition which it must satisfy, that all the numbers of molecules which are obtained correspond to polyhedrons comprehended in the foregoing table, soon makes known that one of these different suppositions which can agree with the entire whole of the phænomena: it then becomes easy to calculate the respective weights of the molecules of all the simple bodies; and these weights once determined, it is sufficient to have a pretty close analysis of a compound body, and to know how much its particles contain of molecules of each of its elements, and thus correct the inevitable errors of analysis.

Several chemists have endeavoured to attain the same result by determining the respective weights of certain proportions of the different simple bodies which always enter an entire number of times into the bodies which are composed of them. These proportions do not lead to results conformable to the experiments, but when they are always multiples or submultiples of the respective weights of the molecules: but when we make use of them, nothing can indicate how many of the proportions of a simple body ought to enter into one of those compounds; whereas the consideration of the representative forms shows, in many cases, how much in a compound body there ought to enter of molecules of each of its elements, and even leads us to establish between the combinations of two simple bodies with all the others, such a dependence, that, the combination of one of those bodies being known, we may foresee those of the other. I have found for instance, by comparing the combination which oxygen and hydrogen form with different bodies, that, with the exception of chlore and sulphur, the combinations of which with hydrogen present the properties of the acids, one same quantity of a body susceptible of being united to hydrogen is combined in such a manner, that there are in general, in each of the particles of the compound, four molecules of hydrogen more than there are molecules of oxygen in the corresponding combination of the same body with this last gas. We may even remark, that when this body forms with oxygen several combinations, some of which are more difficult

difficult and the others more easy to decompose, the compounds of hydrogen corresponding with the first in the manner which I have explained, are the only ones which can be obtained, at least in the isolated state; and that those which correspond in the same manner with the less stable combinations of oxygen are either impossible, or cannot exist but when united to a third body. According to this addition of four molecules or of an entire particle of hydrogen to the number of the molecules of oxygen assumed by the different bodies in their most stable combinations with this last gas, we find six molecules of hydrogen when there are two of oxygen in these combinations, and eight when there are four.

The same considerations also lead us to foresee, according to the representative forms of their particles, what are the gases which water cannot absorb, but in very small quantity, by the simple interposition of some of their particles between those of water, and those which the same liquid is susceptible of absorbing in large quantities, and forming with them true combinations.

[To be continued.]

XXXV. *On Mr.* FEARNE's *Observations on external Perception, &c.* *By* T. FORSTER, *Esq.*

To Mr. Tilloch.

SIR, IN a paper On external Perception, recently published in the Pamphleteer, by Mr. Fearne, he has maintained an opinion that our perception of external objects is not by means of the five senses alone, but that it is an act of the mind. As this doctrine, at least as expressed in the manner he has delivered it, is somewhat novel; and as it coincides with an opinion which has resulted from the last discoveries into the physiology and structure of the organs of the brain, I am induced to point out to the metaphysical speculator the great similarity of opinions drawn from different sources, on a subject which has so frequently engaged the attention of philosophers. I do not proceed with Mr. Fearne in all his reasonings throughout the course of his various metaphysical inquiries, but allude specially to the opinion that the sensation of objects by means of the five external senses is not sufficient to produce the belief of the external existence of bodies. But I believe the perception of the external bodies to be the consequence of an organic apparatus quite as material as the nerves of the five senses. In short, the organ of individuality, or that part of the front lobes of the brain above the nose, in the middle and inferior part of the forehead, is ever find myself at issue with the *practical* Colliers, Miners, &c. but on matters of *inference*, or involving their belief, of things *not actually seen by themselves*, I almost daily, when on my Mineral Surveys, find myself point blank at issue with them, and so have been obliged to continue, in numerous instances;—I am, I hope, alike incapable of being influenced by *numbers*, to adopt or reject any position or deduction to be made from the study of Geological phænomena, as I am of yielding in any such cases to *authority*, however academical or imposing its aspect may be; nor will I stand quietly by and see, a most deserving Individual and Friend, deprived of the just reputation due to his labours and discoveries, or neglect the attempt, at contributing towards his more solid reward. And I am,

Sir,

Your obedient servant,

12, Upper Crown Street, Westminster, May 3, 1815. JOHN FAREY, Sen.

LXII. *Letter from M.* AMPERE *to Count* BERTHOLLET, *on the Determination of the Proportions in which Bodies are combined, according to the respective Number and Arrangement of the Molecules of which their integrant Particles are composed.*

[Concluded from p. 193.]

WE may also deduce from this manner of conceiving the composition of bodies, the relations of the quantities of acid, basis, and even of water of crystallization, which ought to be found in the acid salts, the neutral, or those that are hypersaturated with one and the same species, according to the representative forms of the particles of the acid and the base. It is thus, for instance, that we find, according to that of the particles of the sulphuric acid, that most of the supersaturated sulphates ought, conformably to experience, to contain three times more bases than the neutral sulphates, and that the quantity of sulphuric acid is double in the acid sulphates to what it is in the neutral sulphate; whereas the sulphurous acid may, according to the representative form of its particles, make with ammonia an acid salt, into which it enters in greater quantity than into the neutral sulphite, in the ratio of three to two only. Such, in short, is the acid sulphite which we obtain by distilling the neutral sulphate of ammonia.

I shall not enter here into the details contained in my full memoir on the different combinations of ammoniacal gas with the other acid gases: the accordance of the results to which we are

are led, with those of the experiment, seems to me one of the most remarkable proofs of the theory therein detailed: but in order to give an example of the manner in which we may draw from this theory the determination of the quantity of water which is combined with bodies, either in the state of crystallization or even after they have undergone the action of a strong heat, I shall cite the determination according to the representative form of the particles of potash from the quantity of water which is united with it in these two states. After having established, setting out from the phænomena which potassium exhibits when we place it in contact with water and ammoniacal gas, that the particles of potash have as their representative form an octohedron composed of two molecules of oxygen and four of metal, I find that, in the crystallized hydrate, the quantity of the oxygen of the water ought to be double that which is united to the potassium; but after the hydrate has been fused, those two quantities of oxygen ought to be as 4 : 3, because a particle of hydrate in this state has for its representative form a heptaoctohedron formed by the meeting of a trioctohedron composed of three octohedral particles of potash and of a tetraoctohedron of four octohedral particles of water. Now, according to the composition of potash as determined by Messrs. Thenard and Gay Lussac, 100 parts of potassium unite with 19·945 parts of oxygen to make 119·945 of potash. It follows from what I have said, therefore, that this quantity of potash ought to retain, at every temperature, a quantity of water in which there is 26·593 of oxygen, and which consequently weighs 30·139; that is to say, nearly $\frac{1}{400}$th of the weight of the potash, as has been found by the most accurate analyses.

The combinations of oxygen, hydrogen, and chlore, either with themselves or with other bodies, have been successively the subjects of researches analogous to those just mentioned. As it is impossible to indicate all the results here, I shall confine myself to those of the combinations in which all the elements may be obtained in the state of gas, and in which the numbers of the molecules of each of their elements are consequently given immediately.

We have already ascertained the representative forms of the particles of two combinations of azote and of oxygen, the oxide of azote and the nitrous gas; that of the nitrous acid ought to be determined according to the ratio of the volumes of nitrous gas and oxygen of which it is composed. Experiments have been made upon this subject, but their results are at variance. According to the analyses of Sir Humphry Davy, this acid is composed of two volumes of nitrous gas, and of a volume of oxygen: each of its particles will then contain two molecules of of oxygen more than the particles of nitrous gas, and will consequently have, as the representative form, an octohedron composed of two molecules of azote and four of oxygen; but then, as in all the other combinations where the volume of one of the components is double that of the other, the volume of nitrous gas will not change by the addition of oxygen: the greatest condensation which takes place appears to me to be ascribable to this, namely, that in proportion as these octohedrons are formed, they are combined in hexa-decahedrons, with tetrahedrons of nitrous gas. As two molecules of oxygen are then sufficient for the formation of one of these hexa-decahedrons into which two entire particles of nitrous gas enter, the volume of oxygen is only the fourth part of that of the nitrous gas, and the volumes of azote and oxygen are, in the nitrous acid, as 4:6. These results agree with the experiments of M. Berzelius. On this hypothesis, the condensation ought to be 3-fifths of the total volume; but it will not take place completely except when, the oxygen being introduced by small portions into the nitrous gas, the octohedrons just mentioned, in proportion as they shall be formed, will meet an excess of tetrahedron of nitrous gas with which they may be combined. If we introduced, on the contrary, the nitrous gas into oxygen, a part of these octohedrons might remain isolated, and there might result combinations and condensations in variable proportions.

It follows from the composition of the nitric acid, as determined by Sir H. Davy, and which is confirmed by the decomposition of the nitrate of ammonia, that a particle of this acid, if we can obtain it without water, will be composed of one particle of azote and of two particles and a half of oxygen. It will then contain four molecules of azote and ten of oxygen; and we may conceive it as formed by the meeting of two tetrahedrons of nitrous gas joined to an octohedron of six molecules of oxygen *, and forming with it a dodecahedron. But in the combination which this acid always forms with water, we must suppose that the octohedron of oxygen and two octohedrons of water form a trioctohedron which is united in a trapezoidal form with the two tetrahedrons of nitrous gas: we may hence conclude what is the quantity of water in the most highly concentrated nitric acid, and we find by calculation that it is nearly what Dr. Wollaston has determined by his experiments.

In the nitrate of ammonia, a particle of dry nitric acid is united to two particles of ammoniacal gas; so that one particle

* We may also suppose that, in the formation of the nitric acid, the hexa-decahedron of nitrous acid is joined to a tetrahedron of oxygen, which always forms a combination of an octohedron with two tetrahedrons, and changes nothing in the following explanations.

of

of salt is formed by the junction of one octohedron of oxygen, two tetrahedrons of nitrous gas, and four tetrahedrons similar to those which enter, to the number of two, into each particle of ammoniacal gas: the representative form of this particle is therefore a pyramidated hexa-tetrahedron, containing ten molecules of oxygen, eight of azote, and twelve of hydrogen. When we decompose the salt by heat, the eight molecules of azote form two particles of oxide of azote with four molecules of oxygen, and the twelve molecules of hydrogen form three particles of water with the six other molecules of oxygen.

When the salt contains besides water of crystallization, we ought to obtain more than three particles of water; but in all cases, we can only extract from its decomposition water and oxide of azote, as we find by experience.

If the quantity of water of crystallization was equal in the salt to that which is contained in the most highly concentrated nitric acid, it would be necessary to join to the octohedron and to the six tetrahedrons of which one of the particles is composed, two other octohedrons of water; which will give for the representative form of the crystallized nitrate of ammonia, an octo-centahedron formed by the meeting of six tetrahedrons and one-trioctohedron. Chlore is combined with hydrogen in equal volume, and the muriatic acid gas which results occupies a volume equal to the sum of the volumes of those two component parts. We might account for this mode of combination, by supposing that the representative forms of the particles of chlore are isolated tetrahedrons like those of oxygen, azote, and hydrogen; that of the particles of the muriatic acid will then be a tetrahedron: but we may also explain it by considering each particle of chlore as formed by the meeting of two tetrahedrons in a parallelopipedon, and as consequently containing eight molecules. This last hypothesis is the only one which can agree with the proportions of the other combinations of chlore, the phænomena which they exhibit, and the properties which characterize them.

By admitting it, we find that each particle of muriatic acid, containing the half of a particle of hydrogen and the half of a particle of chlore, has for its representative form an octohedron composed of two molecules of hydrogen and four molecules of chlore. When the muriatic gas is combined with the ammoniacal gas, each of its octohedrons is combined with a cubic particle of this gas: hence it follows, that it ought to absorb of it a volume equal to its own, as experience shows, and that the particles of the salt thus formed ought to have as their representative form a rhomboidal dodecahedron: this form is, in fact, one of those which belong to the system of crystallization of of sal ammoniac, and all the others might consequently be referred to it by different decrements. The acid gases, the particles of which have a cube for their representative form, tend, on the contrary, to combine with the ammoniacal gas in such a way that the volume of one of the gases is double that of the other, because the most simple polyhedron which we can form with cubes is the hexa-tetrahedron which contains three of them.

The composition of the gas formed by the meeting of oxygen and chlore, which Sir Humphry Davy has discovered and called euchlorine, is one of the most remarkable, from the proportions in volumes of its two component parts. According to his analysis, five volumes of the gas which he submitted to the experiment, gave, on being decomposed by heat, two volumes of oxygen and four of chlore. These relations seem contrary to all analogy, and they seem to be inadequate to the explanation of the composition of the particles of euchlorine, without admitting that the gas analysed by this celebrated chemist was mixed with a little chlore; a supposition which naturally occurs when we recollect that the process by which this gas was obtained gave a mixture of euchlorine and chlore, from which this last gas was separated by shaking it over mercury; a process which probably did not take up all the chlore, and which, besides, did not leave any method of ascertaining, even if successful, that the residue of this operation was pure euchlorine.

I think therefore that we must account for this analysis, by supposing that the gas employed contained one-fifth of chlore; and that, of the five volumes submitted to the experiment, there were four only of a gas really composed of oxygen and chlore. By supposing that the representative form of its particles is a cube composed of two molecules of oxygen and five of chlore, we find that four particles of this gas ought to contain eight molecules, *i. e.* two particles of oxygen and twenty-four molecules, *i. e.* three particles of chlore: so that the decomposition of four volumes of pure euchlorine would produce, upon this hypothesis, two volumes of oxygen and three volumes of chlore. These three volumes of chlore united to a volume of the same gas, which formed by its mixture with the four volumes of euchlorine the five volumes which were operated upon, ought to have given in the residue the four volumes of chlore found by Sir Humphry Davy.

The relation of three volumes of chlore and two volumes of oxygen in the euchlorine, seems at first to present no analogy with the relations which we observe in the combinations of the other gases; but this anomaly is only apparent, and merely arises from the tetrahedrons of the chlore, instead of being separated like the tetrahedrons from the oxygen, the hydrogen, and

and the azote, remaining combined by pairs in each particle of chlore; so that a volume of this gas is equivalent to two volumes of another gas relative to combinations; and that if the tetrahedrons of the chlore shall all be separated from each other, we shall obtain, by the decomposition of the euchlorine, six volumes of chlore and two volumes of oxygen, precisely as we find in the residue from the decomposition of ammoniacal gas, the particles of which have the same representative form with that of the euchlorine, six volumes of oxygen and two of azote.

The results which I have just indicated form but a very small part of those which we may deduce from the consideration of the representative forms of the particles of bodies applied to the determination of the proportions of inorganic compounds. The chemistry of organized bodies also presents numerous application of this theory; but it is in this respect particularly that there are many analyses and calulations to make for completing it. I have nevertheless drawn several determinations relative to the composition of different circumstances drawn from the vegetable kingdom, which agree too strongly with the results of experience to leave any doubts as to the utility of which it may be in this part of chemistry.

LXIII. *Some Experiments and Observations on the Colours used in Painting by the Ancients. By Sir* HUMPHRY DAVY, *LL.D. F.R.S.**

I. *Introduction.*

THE importance the Greeks attached to pictures, the estimation in which their great painters were held, the high prices paid for their most celebrated productions, and the emulation existing between different states with regard to the possession of them, prove that painting was one of the arts most cultivated in ancient Greece: the mutilated remains of the Greek statues, notwithstanding the efforts of modern artists during three centuries of civilization, are still contemplated as the models of perfection in sculpture; and we have no reason for supposing an inferior degree of excellence in the sister art, amongst a people to whom genius and taste were a kind of birthright, and who possessed a perception, which seemed almost instinctive, of the dignified, the beautiful, and the sublime.

The works of the great masters of Greece are unfortunately entirely lost. They disappeared from their native country during the wars waged by the Romans with the successors of Alexander, and the later Greek republics; and were destroyed

* From the Philosophical Transactions for 1815, part i.

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