LI. An attempt to determine the definite and simple proportions, in which the constituent parts of unorganic substances are united with each other

Jacob Berzelius M.R.A.

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The foregoing experiments and observations will, if I mistake not, place the electric column in a new point of view; for to its other singular properties may be added that of an *hygrometer*: they will likewise account in an easy, natural, and satisfactory manner for the phenomenon observed by Mr. De Luc, and described by him in Nicholson's Journal; without compelling us to have recourse to the hypothesis of "the production of a new quantity of electric fluid in the column by the sunbeams*."

The same may be said concerning the phenomena noticed by Mr. Singer when he placed an electric column, and a bell-ringing apparatus, before a fire†.

In the experiments alluded to, the *heat dispersed* from between the extremities of the columns the moisture which impaired the insulation; and thus enabled the electromotive power of the instruments to produce a greater accumulation and deficiency of electric fluid at their opposite extremities than could possibly exist while that moisture was interposed between them.

I am, &c.

THOMAS HOWLDY.

To Messrs. Nicholson and Tilloch.

LI. *An Attempt to determine the definite and simple Proportions, in which the constituent Parts of unorganic Substances are united with each other.* By JACOB BERZELIUS, Professor of Medicine and Pharmacy, and M.R.A. Stockholm.

[Concluded from p. 175.]

IV. GENERAL VIEW OF THE RESULTS OF THE EXPERIMENTS RELATED IN THESE DIFFERENT ESSAYS.

1.

WHEN two substances, which we consider as simple, are capable of being united in more than one proportion, these proportions, for a given quantity of the [positively] electrical body, are multiples by $1\frac{1}{2}$, 2, 4 . . . of the least proportion in which the [negatively] electrical body is capable of combining with it.

[We must not, however, understand this multiplication of proportions in the strict mathematical sense of the terms, which is equivalent to the involution of powers, but simply as relating to the multiplication of the quantities by the numbers in question. Gilbert.]

There are however many phenomena which make it probable, that the multiple $1\frac{1}{2}$ is only apparent; and hence it follows, that the combination, from which it is deduced, does not exhibit the

* Nicholson's Journal, vol. xxxvi. p. 315. † Ibid. p. 374.

true minimum, but that there are other lower proportions, according to which it may be a multiple by 6, 12, or 18. Thus, for example, the arsenic acid contains once and half as much oxygen as the arsenious; but the black oxide of arsenic, which is formed by the oxidation of the metal in the open air, contains only one-fourth as much oxygen as the arsenious acid; and hence the oxygen of this acid is truly a multiple by 4, and that of the arsenic acid by 6, of the oxygen in the black oxide. I have shown how a similar remark is applicable to the acids afforded by sulphur.

The progressions hitherto discovered are expressed in even numbers. The only exception is the progression for the combinations of oxygen with ammonium, which, if we set aside the possibility that hydrogen may be an oxide, will advance in the following irregular manner: 1, $1\frac{1}{2}$, 3, $4\frac{1}{2}$, 6, $7\frac{1}{2}$; that is, supposing the oxygen of ammonia to be unity. Hence we may infer that this series cannot begin from the true minimum, and that there must be lower stages of oxidation of ammonium, than nitrogen, one of which must probably be identical with hydrogen. If then the oxygen of nitrogen is a multiple of the oxygen of hydrogen by 6, 12, or 18, the series will become perfectly regular. I must also remark, that from the point at which ammonium changes its electro-chemical modification in forming nitrogen, the series proceeds with greater multipliers.

The relations, which are found between the component parts of more complicated substances, are all conformable to the laws which regulate the simpler combinations; for instance, the proportions of sulphur to iron in the sulphates.

2.

When two oxygenized bodies are combined, their proportion may be most readily determined from the quantities of oxygen which they contain, the one being always either equal to the other, or to an integral multiple of it.

To these combinations belong:

a. Salts. In *neutral salts* the oxygen of the acid is a multiple by 2, 3 . . 8 of that of the base. In the *supersalts* the number may be still higher. In the *subsals*, the oxygen of the acid is sometimes a multiple of that of the base, sometimes equal to it, and not uncommonly an integral submultiple.

b. Hydrates, or combinations of water: first, with acids. In these the water takes completely the place of a base; the acid takes up a quantity of it which contains exactly as much oxygen as any other base with which it would be saturated: and this water is totally distinct from the water of crystallization contained by some of the acids.

Secondly:

Secondly: with bases. Here the water takes the place of an acid, but contains only an equal quantity of oxygen with the base, or sometimes even a submultiple only. The water of crystallization is here again distinct from the water combined in the place of an acid.

c. Combinations of alkalis, earths, and oxides, with each other in pairs. Although my experiments exhibit no example of such a combination, it is obvious that it must be classed in this place. For, whether we call the oxides of chromium, molybdenum, tungsten, tantalum, and tin, acids or oxides, the rule must be equally applicable to them, and that which is a law for one oxide must also hold good with respect to others. Besides, since such combinations of two bases are the foundations of double salts with double bases, and since the law prevails with respect to these salts, we may consider this as a sufficient proof of the general law.

Combinations of two acids belong also here, for example, the fluoboric acid, in which the weaker acid probably occupies the place of a base.

3.

When three or more oxygenized bodies unite with each other, the oxygen of the body which contains the smallest quantity is a common divisor, or rather an aliquot part of the oxygen of the others, each of which must therefore be an integral multiple of this smallest quantity.

To this law belong:

a. Salts containing water of crystallization. In the *neutral salts* the water of crystallization contains 1, 2, 3, 4, 5 . . times as much oxygen as the base, or more rarely $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ as much. In *subsals* in which the oxygen of the acid is a submultiple of that of the base, the water of crystallization contains a quantity of oxygen which is a multiple of both the quantities, in the acid and in the base.

b. Double salts. Examples of salts in which the oxygen of the one base is either equal to that of the other, or an integral multiple of it, are afforded respectively by the double salts of ammonia and magnesia, and by alum. When water of crystallization is present, the substance is a quadruple compound, and the oxygen of the component part, which contains the least of it, is a common divisor, or an aliquot part, of the oxygen of the others, as we have seen in alum, in which the oxygen of the potass is contained three times in the alumina, 12 times in the sulphuric acid, and 24 times in the water.

c. Combinations of several alkalis, earths, and oxides, including crystallized minerals. Although we are not authorized

by any direct experiment related in these Essays to form a conclusion respecting crystallized minerals; there is however no doubt of its validity; for why should marble, fluor spar, and ponderous spar, be formed according to a law which is not applicable to other minerals? Such a diversity is scarcely conceivable.

On the other hand, the application of the rule will obtain for mineralogy a degree of mathematical certainty, and afford to chemists, who are engaged in the analysis of minerals, a ready mode of satisfying themselves, how far their operations are correct; while, without some such means, these analyses can never be brought to a sufficient degree of accuracy. It is true that, according to this view of the subject, the greater number of such analyses, even when performed by the greatest masters, can only be considered as approximations, which in many cases scarcely come at all near to the truth; but such is the ordinary course of human labours. Since Bergmann's analyses of salts, which were so masterly for his time, 30 years are scarcely elapsed, and yet many of them can at present hardly even be called approximations. And the numerical determinations of the proportions of mixture of various substances, which I have attempted to obtain with the greatest care, and with the utmost possible accuracy, and which I have inserted in this Essay; will certainly not be sufficient for the future; and it will be possible, with the assistance of the laws here developed, to correct them, and to bring them nearer to the truth. But I am confident that our successors will pardon the imperfections of my experiments; as it must be allowed that chemistry, in its present state of advancement, must still be grateful for the valuable labours of Klaproth, Vauquelin, and others, although most of their analyses are become insufficient for its purposes of progressive investigation.

4.

Lastly, when several combustible substances, which we consider as simple, unite with each other, the proportions, in which these combinations are possible, are determined by their capacity for oxygen, the combinations taking place in such a manner, that, if they were oxidated in a certain degree, the oxygen taken up by one of the substances, would be a multiple by 1, 2, 3 . . . of the quantity taken up by the other. Thus sulphur, phosphorus, and arsenic, unite with metals in such proportions, that a salt may be produced by the oxygenization of the compound, or at least would be produced according to the general rule.

The same is also true of other metallic compounds, which are separated from mixtures in a state of fusion, by chemical causes, such as crystallization or heat: for instance, of crystallized amalgams,

gams, or crystallized alloys, which are sometimes obtained in purifying metals by assaying them. The union by fusion is analogous to the solution of a salt in water; and may be effected in almost all proportions: but when a salt crystallizes, a definite combination with water takes place; and when crystalline alloys are formed in the gradual cooling of mixtures, the part, still fluid being poured off, the crystallized part exhibits a fixed and definite combination. When a combination of two metals is capable of affording saline bases by oxidation, each part, in its conversion into a protoxide, commonly takes up the same quantity of oxygen. The *arbor Dianæ* affords an example of such a combination which is easily examined. When a compound contains several metals, it may happen that some of the multipliers may be very large. It is difficult to obtain such combinations in a state of purity; and I must defer, for the present, the publication of the few experiments which I have hitherto made on them.

The combinations of some combustible substances with oxides, for instance those of sulphur, sulphuretted hydrogen, boracium, and telluretted hydrogen, with alkalis and alkaline earths, follow the same laws, as if they were combined with the metallic radicals of the alkalis or earths without oxygen; or as if they were united with oxygen, and entered into combination, as acids and oxides, with the alkalis or earths.

In these few lines, we have gone through the whole structure of inorganic nature, and have seen, how it may be reduced to a few very simple principles. Oxygen, the only absolutely [negative] substance in all nature, is every where the standard, by which the proportions between the component parts of all combinations may be measured. From the existence of such a common measure, it follows, as a necessary consequence, that compound bodies, when they mutually decompose each other, never, or at least very seldom, set at liberty a single atom of their component parts; that neutral salts, for example, decompose each other without losing their neutral condition; and that sulphurets decompose water without disengaging hydrogen.

It is unnecessary to expatiate here on the additional importance which chemistry gains, as a science, by such a reduction of its results to mathematical principles. This is however still but an inconsiderable step towards the mathematical perfection of the science; and it requires the united and powerful exertions of all chemical philosophers, to bring it nearer and nearer to the elevated rank, which it may be hoped that it will ultimately attain in the system of human knowledge.