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I.—*On the Constitution of Acids and Salts.*

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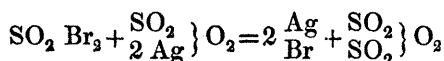
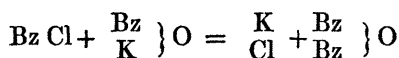
The object of this communication is to show, how all salts, whether acid, neutral, or basic, whether containing metallic protoxides, binoxides, sesquioxides, or teroxides, whether monobasic, bibasic, or tribasic, may be respectively reduced to the type of one or more atoms of water, representing water as $\begin{matrix} \text{H} \\ \text{H} \end{matrix} \} \text{O}$.

It has, I believe, been shown by the researches of Messrs. Williamson and Gerhardt, that the ethers, alcohols, and organic acids not only may, but must be reduced to this type. The notions here brought forward were originally suggested by their papers, and may be considered in great measure as elaborations of views introduced by them from time to time to the notice of this Society. I believe, however, that the formulæ I have ventured to accord to the phosphates, are quite original.

The representation of monobasic salts as homologues of water ($\begin{matrix} \text{NO}_2 \\ \text{K} \end{matrix} \} \text{O}$ nitrate of potash,) is now I believe, not unusual. Dr. Williamson has also given illustrations of the mode of representing bibasic salts in a similar manner; but in the illustrative salts brought forward by him, the bibasic characters of the salts depended entirely upon the bibasic nature of their acid

constituents, the representation of bibasic salts—bibasic from the nature of their bases—being, I believe, unattended to. With regard to Gerhardt's experiments upon the anhydrous acids, an objection has been raised to them, to the effect, that the new compounds procured by his new process need not necessarily stand to their respective hydrated acids in the same relation that the well-known anhydrous acids stand to their hydrates, or, in other words, that he, by his new process, has not produced any previously recognised anhydrous acid, but simply certain compounds which, after all, may perhaps be only isomeric with the true anhydrous acids. With the view of refuting any such objection, I sought for a method of making some well-known anhydrous acid, on a plan similar to that which he adopted for preparing his new anhydrides. For this purpose I availed myself of a new substance (a product of some experiments made by Mr. Abel and myself) viz., the bromosulphuric acid, a white, solid, crystalline volatile body, analogous to Regnault's chlorosulphuric acid.

This substance was sealed in a tube with excess of sulphate of silver, and heated in an oil-bath. Bromide of silver and anhydrous sulphuric acid resulted, in the same manner as, by heating chloride of benzoyl and benzoate of soda, we obtain chloride of sodium and anhydrous benzoic acid.



the only difference between the two equations being, that the one represents the formation of a monobasic, and the other that of a bibasic anhydride.

For the building up of the formulæ I am about to submit to you, it is necessary—to accord to different substances different representative values, and occasionally to the same substance under different conditions, likewise different representative values—to avail myself of an illustration made use of by Dr. Williamson on a previous occasion in the case of tin. The atom of tin has usually a replaceable, or representative, or substitution value, equal to that of hydrogen, as seen in the formulæ H Cl and Sn Cl ; but, under certain circumstances, its equivalent becomes, as it were, doubled, and in substitutions the atom of tin has a representative value equal to that of 2 atoms of hydrogen, as seen in the formulæ H H Cl_2 and Sn Cl_2 .

In the same manner iron has two replaceable values, equal respectively to 1 and $1\frac{1}{2}$ atoms of hydrogen; bismuth a representative value equal to 3 atoms of hydrogen; mercury and copper two representative values, and so on. Now for the clear elucidation of the succeeding formulæ, I adopt in them, a simple plan of marking these different substitution values, viz., by one or more dashes to the right or left of the symbol, something after the fashion frequently made use of in algebraical formulæ: thus,

H', an atom of hydrogen.

Sn', an atom of tin, as existing in stannous salts, having a substitution value equal to that of hydrogen.

Sn'', the same atom of tin, having the same atomic weight, but existing in stannic salts, and having a substitution value equal to that of 2 atoms of hydrogen.

Bi''', an atom of bismuth, as existing in bismuth salts, having a value represented by 3 atoms of hydrogen.

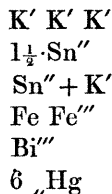
Fe', an atom of iron, as existing in ferrous salts, having a replaceable value equal to that of hydrogen.

Fe Fe''' or Fe'''₂, 2 atoms of iron, as existing in ferric salts, having together a substitution value equal to that of 3 atoms of hydrogen.

Hg', an atom of mercury, as existing in mercuric salts, having a substitution value equal to that of hydrogen.

„Hg, an atom of mercury, as existing in mercurous salts, having only half the replaceable value of an atom of hydrogen.

From this it is evident that in making equivalent substitutions for 1, 2, or 3 atoms of hydrogen respectively, the number of atoms introduced may vary very considerably, provided the total exponential value remains the same: thus, 3 atoms of hydrogen, H' H' H', may be alike perfectly represented by



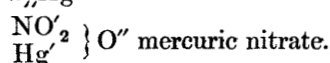
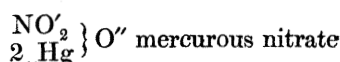
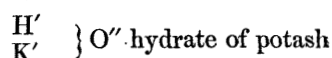
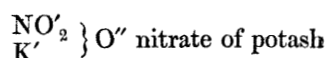
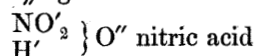
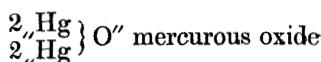
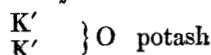
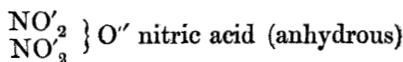
in each of which cases, the same exponential value is maintained, notwithstanding the difference in the numbers of the atoms.

I proceed to offer some general illustrations of compounds formed on the types of 1, 2, and 3 atoms of water respectively.

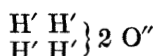
One atom of water being taken as the type



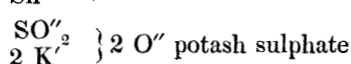
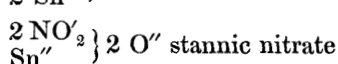
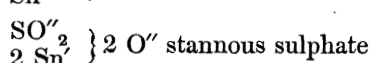
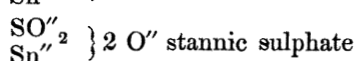
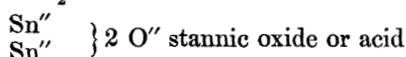
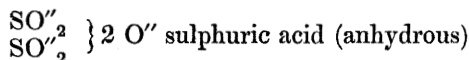
it is obvious that each or either of the atoms H' can only be replaced by x' or $2_{//}x$, thus :

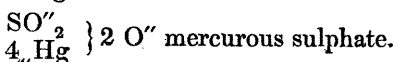
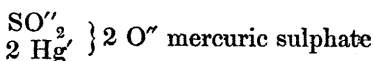
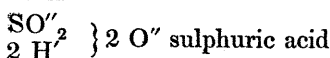
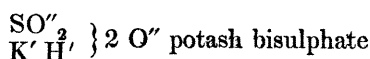


Two atoms of water being taken as the type

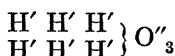


One pair of H' H' being generally represented by x'' , the other by x'' , or $2 x'$ or $4_{//}x$, thus :





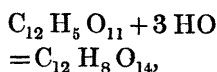
Three atoms of water being taken as the type :



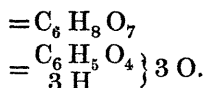
One tierce of $\text{H}' \text{H}' \text{H}'$ being generally represented by some substance having obvious tribasic tendencies, as x''' , or xx''' , or $x'' + x'$; the other tierce being represented by x''' , or xx''' , or $x'' + x'$, or $1\frac{1}{2}x''$, or $3x'$, or $6x$.

In order to illustrate this series, I must make use of some tribasic acid, and avoiding the phosphoric acids for the present, avail myself of an organic acid, the citric.

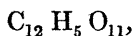
The ordinary formula for hydrated citric acid is :



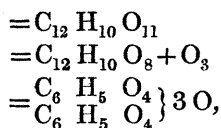
and, by adopting the small equivalent for hydrogen,



In the same manner the formula for hypothetical anhydrous citric acid is :

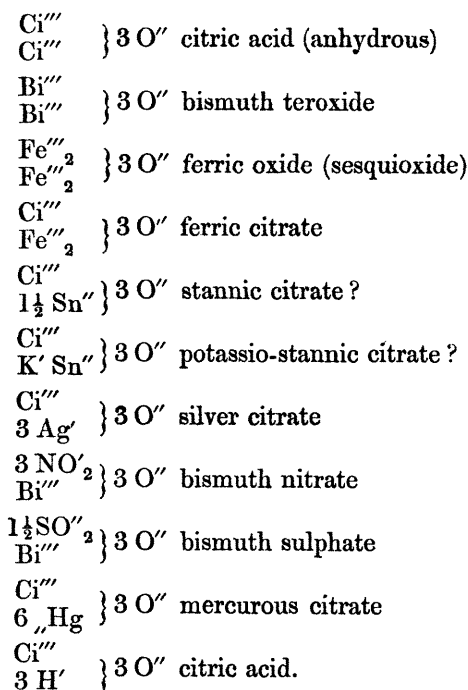


by adopting the small equivalent for hydrogen,

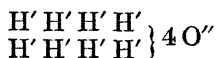


in accordance with the previously used formulæ for the anhydrous acids.

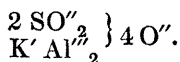
Let Ci therefore stand for the compound $\text{C}_6 \text{H}_5 \text{O}_4$, and have a substitution value accorded to it equal to the value of 3 atoms of hydrogen, as in the following series :



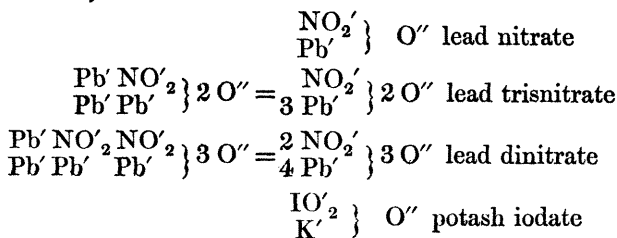
Four atoms of water being taken as a type,

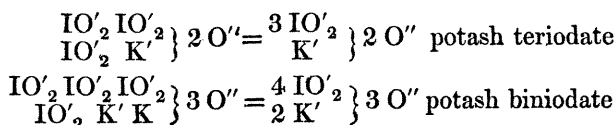


without going into details concerning this group, it may suffice to cite alum as an example,



All the salts hitherto brought forward are strictly neutral in composition: the formulæ are, however, equally applicable to basic and acid salts, as seen below:

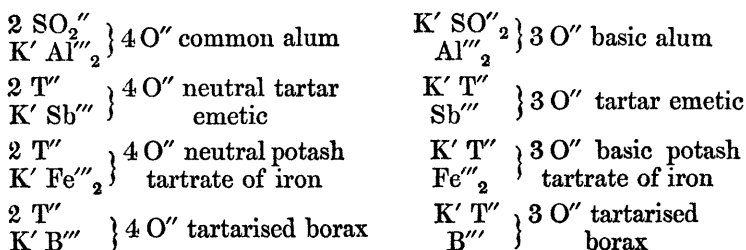




A similar mode of notation is applicable to the salts of chromic acid, by which means, the bichromates and terchromates are made to appear as perfectly normal compounds.

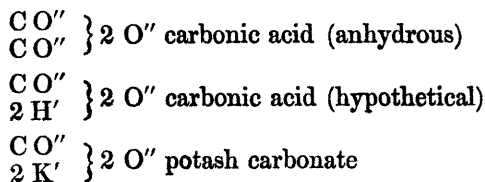
The series of salts formed on the tartar emetic type are very clearly represented by these substitution formulæ, more especially when contrasted with salts of the alum type. The salts of both series agree in containing an atom of a monacid base, associated with an atom of a teracid base; those of the one class, however, being neutral and formed on the type of 4 atoms of water, those of the other being basic and formed on the type of 3 atoms of water.

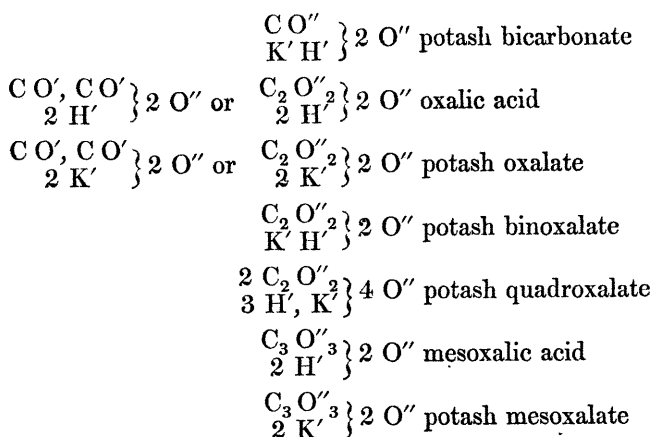
Tartaric acid = $\text{C}_4\text{H}_4\text{O}_4'' \} 2 \text{O}'' = \text{T}'' \text{H}' \} 2 \text{O}''$ then we shall have



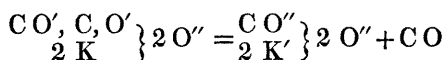
I shall now endeavour to show the applicability of these views to certain series of salts, and for this purpose select the carbonates, sulphates, and phosphates, with their respective congeners.

And first, with regard to the carbonates, it will be seen that both carbonates and oxalates may be regarded as oxidised compounds of carbonic oxide with metals, but that in the former class the atom of carbonic oxide has a replaceable value equal to that of 2 atoms of hydrogen, whilst in the latter it has a value equal only to that of 1 atom of hydrogen. Similar considerations apply to the mesoxalates.

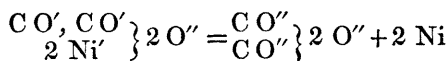




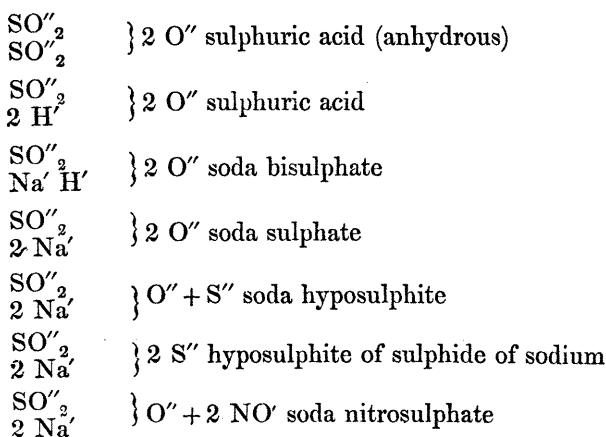
The action of heat on oxalate of potash is very clearly seen in these equational formulæ :

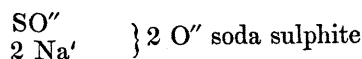
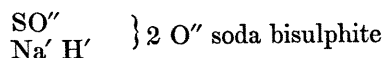
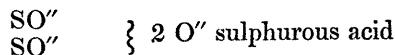
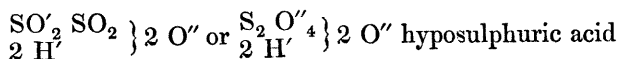
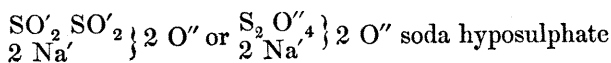


also the action of heat on oxalate of nickel :

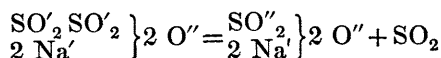


The following table represents in a similar manner the acids of sulphur and their salts :



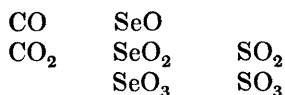


The relations of the hyposulphates to the sulphates are in this way made very apparent. Hyposulphates stand to the sulphates in a position similar to that which the oxalates occupy with regard to the carbonates; and here likewise the action of heat is very clearly portrayed:



In fact, the hyposulphates are sulphates into the constitution of which another atom of sulphurous acid has been forced.

With regard to the sulphites, a radical SO is made use of, which is not known to have any real existence. That such a substance should, however, exist in compounds, is not by any means improbable when we consider the analogies of the sulphites, selenites, and carbonates, as pointed out by Muspratt, and as seen below:



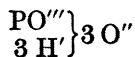
To proceed to a consideration of the acids of phosphorus and their salts, I am desirous of discussing the relations of this series somewhat more fully than those of the preceding ones, and shall venture to premise a few general remarks. It appears to me, that chemists have usually been too prone to regard all irregularities in the properties of bodies, as special differences between such and other more orthodox substances; whereas, a more deliberate examination of the subject would show that most of these apparent differences in kind, were in reality only differences in degree. I think it may be taken as a rule, that every obvious abnormality in the constitution or properties of any particular body, is but an exaggerated condition of quality which exists latent in other bodies;

so that while these abnormal bodies are constantly, and under every variety of circumstance, obtruding their peculiarities upon our notice, it is only by intentional search, and under the most favourable conditions, that the same characters will be found to obtain, though in a less marked degree, in other more normal bodies.

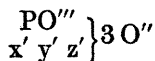
Moreover, we are oftentimes apt to overlook broad features of resemblance between different substances, from the accidental circumstance of such substances having been originally regarded in different aspects; the similitude is, however, rendered at once apparent by simply altering our point of view.

Thus the phosphoric acid is usually considered as peculiar, inasmuch as its saturating power varies remarkably in different instances. Now I believe that by changing our point of view, this property will prove to be not of a special kind, but a special illustration of a general law, prevailing, though to a much lower degree, in other compounds. My object, then, in the succeeding remarks, is to point out the method of representing the phosphates in accordance with the previously used substitution formulæ, and at the same time to show that their so-called peculiarities are manifested, though to a much less extent, in the salts of many other acids, certainly in the chromates, borates, iodates, and sulphates.

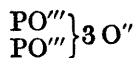
In the first instance, confining myself to considerations connected with the common phosphates and the meta-phosphates, I was desirous to know whether the meta-phosphate ought to be regarded as the normal salt, and the common phosphate as a salt containing an excess of base; or whether the common phosphate was the normal salt, and the meta-phosphate a salt containing an excess of acid. From thinking over the modes of formation and general habitudes of the salts, I was induced to adopt the latter assumption, and to represent ordinary terhydrated phosphoric acid as



any tribasic phosphate



and the anhydrous acid as :



compounds formed on the type of three atoms of water.

Now, if one such atom of a tribasic phosphate containing three

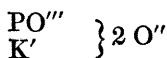
atoms of fixed base were fused with one atom of anhydrous phosphoric acid, one atom of meta-phosphate would result : thus



and the meta-phosphate would be considered as a common phosphate combined with anhydrous phosphoric acid, in the same manner that bichromate of potash is regarded as a combination of neutral chromate of potash with anhydrous chromic acid; biniodate of potash, a combination of neutral iodate with anhydrous iodic; biborate, a combination of neutral borate with anhydrous boric; bisulphate, as a combination of neutral sulphate with anhydrous sulphuric acid, &c.* Now I believe that this analogy will be found to be an analogy proper, having a real existence in fact, and being sufficient to warrant our removing the phosphates from their present isolated position, and to our associating them with other anhydrous acid salts, the number of which I have no doubt might be greatly increased.

There is no difficulty whatever in making the salts agree perfectly well as regards their formulæ, as seen on next page; chromic acid being represented as bibasic, its bibasity being inferred from its analogy to sulphuric acid, and from the vapour-density of its oxychloride.

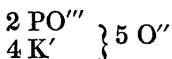
Wurtz's views of the constitution of the hypophosphites and phosphites, accord extremely well with these substitution-formulæ, the relations of the former to the metaphosphates, and of the latter to the pyrophosphates, being most fully preserved.



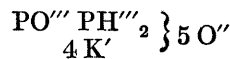
Metaphosphate.



Hypophosphite.

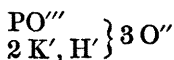


Pyrophosphate.

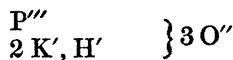


Phosphite.

It becomes a question, however, whether the phosphite might not be better represented as a homologue of the common phosphate,

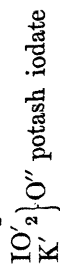


Phosphate of potash, ordinary.

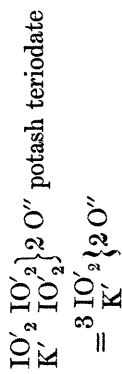


Phosphite of potash, ordinary.

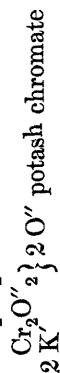
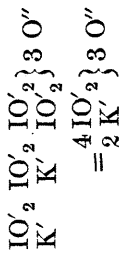
* The bisulphate to which I refer, is that described by Jacquelin, having the composition $\text{KO SO}_3, \text{SO}_3$, analogous to the Nordhausen acid $\text{HO SO}_3, \text{SO}_3$.



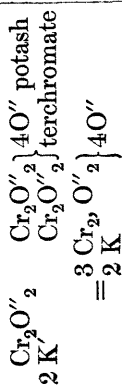
By combining 1 atom of each of the above compounds, we have :



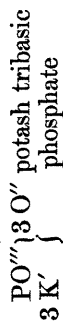
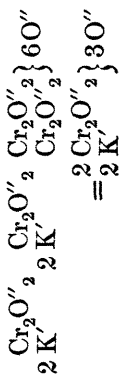
As an intermediate compound between the iodate and teriodate, we have the biniodate :



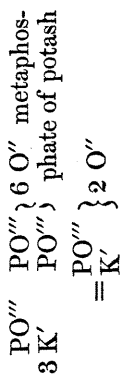
By combining 1 atom of each of the above compounds, we have :



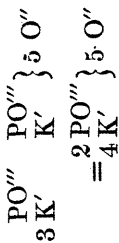
As an intermediate compound between the chromate and terchromate, we have the bichromate :



By combining 1 atom of each of the above compounds, we have :

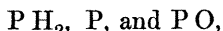


As an intermediate compound between the common and the metaphosphate we have the pyrophosphate :



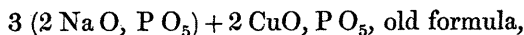
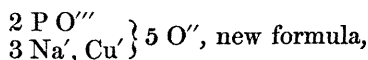
The exact homologue of the bichromates and biniodates is to be found in one of Fleitmann and Henneberg's salts.

By this means we should make use of three phosphorus radicals,



each having a replaceable value equal to that of 3 atoms of hydrogen.*

The mode I have adopted for expressing the pyrophosphates represents most clearly the constitution of certain double pyrophosphates, one of which Mr. Graham has noticed as being inimical to Fleitmann and Henneberg's views.



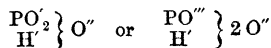
for the double pyrophosphate of soda and copper.

Having thus pointed out the almost complete correspondence of the formulæ of the above salts, I proceed to discuss the correspondence of their properties, and I trust I shall be able to show, that the different members of the series partake of a common character, and that such differences as exist among them are not differences of kind, but only modifications of general properties, depending for the most part upon ascertainable modifying conditions.

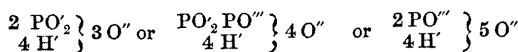
If any of the above anhydrous acid salts be dissolved in an

* Since reading the above paper, Dr. Williamson has pointed out to me, that by making use of another phosphorized radical PO_2 , the phosphates may be represented in a manner different to the above. This difference in the formulæ may perhaps explain the constitution of the two principal classes of metaphosphates and their derivatives.

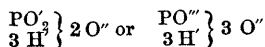
Metaphosphates:



Pyrophosphates:



Common phosphates:



It is to be observed that Dr. Williamson's view makes the metaphosphates analogous to the nitrates:



Nitrate and metaphosphate of soda respectively.

excess of cold water, one of two circumstances will take place ; either the free acid will remain attached to the salt and not take up basic water, as is the case with boric and chromic acids, or the free acid will unite with basic water, gradually, as is the case with the phosphoric acid, or more rapidly, as is the case with the sulphuric.

That the free boric and chromic acids should behave as they do, is easily explicable, when we consider that neither of them forms a definite basic hydrate. That the free anhydrous sulphuric acid should take up water rapidly, is what we might expect, from its powerful affinity for water ; that the free anhydrous phosphoric acid should not take up water so rapidly as does the sulphuric, is accounted for readily, when we consider the different conditions which determined the existences of the salts respectively containing them.

If, however, the above salts be dissolved in boiling water, the anhydrous sulphuric and phosphoric acids alike take up water rapidly, so as to form the normal salts. If, moreover, a solution of potash or soda be used instead of water, the free anhydrous boric, chromic, sulphuric, and phosphoric acids alike take up the added base, to form normal salts : the boric, however, from the feebleness of its acid properties, by which it is obviously fitted to act as an acid adjunct, does not manifest this action to the same degree as do the others.

When common phosphoric acid is heated to a certain point, it loses a definite amount of water, and metaphosphoric acid results from the combination of the naseent anhydrous phosphoric acid with some of the unaltered common acid ; sulphuric acid cannot, however, be changed in this manner, because the anhydrous acid being volatile, the physical action of heat is not opposed to the affinities, as in the preceding case.

The similar blowpipe properties of phosphorus-salt and borax are explained by this view of their similar constitution. In each instance we have free anhydrous acid at an intense heat, extremely fixed, and in a liquid condition ; when a metallic salt or oxide is added, combination takes place as a matter of course, and the borate or phosphate of metal unites with or dissolves in the borate or phosphate of alkali. But if we employ either normal or basic borates or phosphates, we do not get these coloured beads, or at any rate but very imperfect ones, such action as does occur being probably due to the partial replacement of the volatile soda by the fixed metallic oxide.

A further parallelism between the phosphates and chromates is seen below.

The substance $\left. \begin{smallmatrix} \text{Cr}_2\text{O}''_2 \\ 2\text{K}' \end{smallmatrix} \right\} 2\text{O}''$ is unaltered at a red heat.

the substance $\left. \begin{smallmatrix} \text{Cr}_2\text{O}''_2 \\ \text{Cr}_2\text{O}''_2 \end{smallmatrix} \right\} 2\text{O}''$ is decomposed at a red heat—if

the substance $\left. \begin{smallmatrix} \text{Cr}_2\text{O}''_2 \\ 2\text{K}' \end{smallmatrix} \right\} \left. \begin{smallmatrix} \text{Cr}_2\text{O}''_2 \\ \text{Cr}_2\text{O}''_2 \end{smallmatrix} \right\} 4\text{O}''$ be heated to redness,

the $\left. \begin{smallmatrix} \text{Cr}_2\text{O}''_2 \\ 2\text{K}' \end{smallmatrix} \right\} 2\text{O}''$ remains unaltered,

while the $\left. \begin{smallmatrix} \text{Cr}_2\text{O}''_2 \\ \text{Cr}_2\text{O}''_2 \end{smallmatrix} \right\} 2\text{O}''$ becomes decomposed.

The substances $\left. \begin{smallmatrix} \text{PO}''' \\ 3\text{K}' \end{smallmatrix} \right\} 3\text{O}''$

and $\left. \begin{smallmatrix} \text{PO}''' \\ \text{PO}''' \end{smallmatrix} \right\} 3\text{O}''$

are both unaltered by heat alone, but while

the substance $\left. \begin{smallmatrix} \text{PO}''' \\ 3\text{K}' \end{smallmatrix} \right\} 3\text{O}''$ is unaltered at a red heat in

the presence of charcoal,

the substance $\left. \begin{smallmatrix} \text{PO}''' \\ \text{PO}''' \end{smallmatrix} \right\} 3\text{O}''$ is decomposed under similar

conditions. If then

the substance $\left. \begin{smallmatrix} \text{P}'''\text{O} \\ 3\text{K}' \end{smallmatrix} \right\} \left. \begin{smallmatrix} \text{PO}''' \\ \text{PO}''' \end{smallmatrix} \right\} 6\text{O}''$ be mixed with charcoal and

heated to redness,

the substance $\left. \begin{smallmatrix} \text{PO}''' \\ 3\text{K}' \end{smallmatrix} \right\} 3\text{O}''$ remains unaltered, while

the substance $\left. \begin{smallmatrix} \text{PO}''' \\ \text{PO}''' \end{smallmatrix} \right\} 3\text{O}''$ becomes decomposed; or, in

other words, when a metaphosphate is mixed with charcoal and heated to redness, a common phosphate, with 3 atoms of fixed base, results; in proof of which, I offer the following experiments.

If a bead of metaphosphate of soda be heated with charcoal in the reducing-flame of the blowpipe, and then be dissolved in water, the solution will give a yellow precipitate with nitrate of silver.

If the metaphosphate be intimately mixed with an excess of charcoal (free from organic matter, as procured by the incineration of sugar), and the mixture be put into a crucible and kept at a full red heat for some time, inflammable vapours, smelling of phos-

phorus, are given off; fusion does not take place, but the black powder, when heated with water, affords a solution which gives a yellow precipitate with nitrate of silver.

The solution, when evaporated to dryness and ignited, leaves a semicrystalline mass, which by analysis is shown to have the following composition :

| | Calculation. | Found. | Found. |
|-----------------|--------------|--------|--------|
| 3 NaO . | 56.73 | | |
| PO ₅ | 43.27 | 44.56 | 44.31 |

These are the two best results of several analyses. The salt had a powerful alkaline reaction, and absorbed carbonic acid with considerable rapidity; when too intense a heat was employed, some of the phosphate was converted into phosphuret.

These analogies are, I think, sufficient to warrant the views which I have put forward with reference to the phosphates.* At the commencement of my endeavours to apply the substitution formulæ to this class of salts, I experienced considerable difficulty, and was at one time induced to adopt an opinion which I subsequently found had been proposed by Gerhardt, viz., that the metaphosphates were the normal salts, and the pyrophosphates and common phosphates modifications of ordinary basic salts.

I was inclined to this view from a consideration of certain resemblances between the sulphuric and phosphoric acids as commonly represented, and being thereby led to one or two experiments, which, though simple, are not without interest, I venture to allude to them; especially as the results, though at first sight inimical to the views I have above detailed, are quite capable of being explained by them.

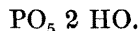
Any dilute sulphuric acid evaporated *in vacuo*, at a temperature of 212° F., becomes SO₃, 3 HO.

By heating the above to a temperature a little above 400° F., we have



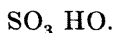
A solution of common phosphoric acid, similarly treated, leaves the compound P O₅, 3 HO.

By heating the above to a temperature of 415° F., we have

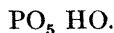


* If Fremy's experiments on the tartaric, tartrelic, and tartralic acids should be ultimately confirmed, that series would afford an abundant illustration, both as regards formulæ, formation and properties, of the correctness of the above mode of representing the meta- and pyrophosphates, viz., as salts containing an excess of anhydrous acid. I was unwilling, however, to draw deductions from results which are still *sub judice*.

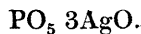
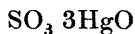
By a further increment of temperature, we have



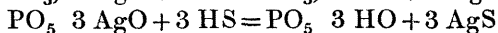
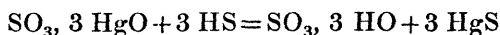
By a further increment of temperature, we have



Again, subsulphate of mercury and yellow phosphate of silver receive similar formulæ :

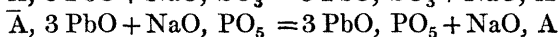
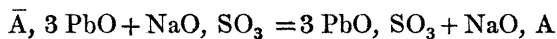


When decomposed by sulphuretted hydrogen, they yield similar acids :



But the salts $\text{SO}_3 \text{ 3 Hg O}$ and $\text{PO}_5 \text{ 3 Ag O}$ are made in very different ways. Being struck with the above analogies, I endeavoured to make similar basic sulphates and phosphates by one and the same method.

For this purpose, I made use of the tribasic acetate of lead, conceiving that by adding a solution of this salt to solutions of sulphate and metaphosphate of soda respectively, I should get formed, by double decomposition, tribasic sulphates and phosphates of lead, as represented below :



that is to say, that the lead phosphate made by decomposing metaphosphate of soda by tribasic acetate of lead, would have the same composition as the lead phosphate made by decomposing common phosphate of soda by neutral acetate of lead. Would it, however, yield the same result when decomposed by sulphuretted hydrogen? would it prove to be a metaphosphate of lead + 2 atoms of oxide of lead, and consequently yield metaphosphoric acid? or would it prove to be the real tribasic phosphate of lead, yielding the common phosphoric acid? I will detail an experiment. Metaphosphate of soda was prepared by ignition of microcosmic salt. The clear glass was broken up in a mortar and dissolved in ice-cold water. Into this solution was filtered an ice-cold solution of tribasic acetate of lead, until the lead-salt remained slightly in excess; the whole was well agitated, thrown on a filter, and washed with ice-cold water. The first portions of the precipitate produced by the lead-salt were redissolved in the excess of metaphosphate; the precipitate permanently resulting had a granular appearance and was very easily washed; the washed precipitate

was mixed with water and decomposed by sulphuretted hydrogen. The whole was allowed to stand in an evaporating dish for about twenty hours, to get rid of the excess of sulphuretted hydrogen. It was then filtered, and the acid filtrate being rendered slightly ammoniacal, nitrate of silver was added, and an abundant yellow flocculent precipitate took place. The colour was not so deep as that produced by adding nitrate of silver to common phosphate of soda, but still it was decidedly yellow, quite as much so as the rind of a lemon. This experiment was repeated several times with slight modifications in its mode of performance; sometimes the lead-salt was added to the metaphosphate, sometimes the metaphosphate to the lead-salt; sometimes the one was in excess, sometimes the other; sometimes the crystalline, and sometimes the glassy metaphosphate was employed. In a few instances, to avoid waiting for the removal of the excess of sulphuretted hydrogen, the gas was only passed through a portion of the suspended precipitate, and when that portion was thoroughly decomposed, the remainder added little by little, agitating between each addition, until all odour was removed, then filtering and applying the silver-test at once. In every trial, the above-described yellow precipitate was obtained: from the same filtrate the appearance of the precipitate occasionally varied considerably, according to accidental circumstances connected with the precipitation, &c. In no case was metaphosphoric acid entirely absent, although sometimes its amount was but very small. A portion of the phosphate of lead with which the above-detailed experiment was made, was partly analyzed.

9·48 grs. of the thoroughly dried precipitate yielded 7·304 grs. of oxide of lead, whereas to have been a real tribasic phosphate it ought to have contained 7·811 grs.

A specimen of basic sulphate of lead, prepared in a similar manner, was examined.

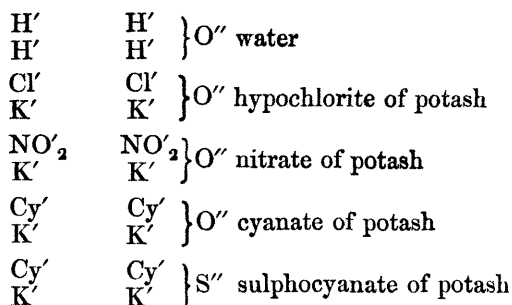
9·69 grs. of the thoroughly dried precipitate yielded 8·35 grs. of oxide of lead, whereas to have been a real tribasic sulphate it should have yielded 8·66 grs.

These results, at the first glance, seem in favour of the idea that the tribasic phosphates should be represented as basic salts; but by looking at the subject from another point of view, we shall see nothing extraordinary in the fact of an acid salt taking up base to become a normal salt, especially when, as in the preceding instance, the base is presented in a sort of nascent state.

There are, however, undoubtedly certain resemblances between common phosphates containing 3 atoms of a powerful base, and

ordinary basic salts, in the same manner as the normal salts of teroxides approximate in their characters to acid salts, and obviously for a similar reason—viz., that in the one case the tribasic acid is incapable of entirely neutralizing the 3 atoms of a powerful base, and in the other the teroxide is incapable of saturating the 3 atoms of a powerful acid; and it is probably this incapacity for thoroughly neutralizing the normal proportions of a powerful base that renders the phosphoric acid, like the boric, eminently fitted to act as an acid adjunct.

With reference to the constitution of such bodies as common salt, muriatic acid, &c., let $\left\{ \begin{smallmatrix} \text{H}' \\ \text{H}' \end{smallmatrix} \right\} \text{O}''$ represent water. If we replace the oxygen by chlorine, we shall have the formula $\left\{ \begin{smallmatrix} \text{H}' \\ \text{H}' \end{smallmatrix} \right\} \text{Cl}'$; but whereas the symbol of water is, so to speak, reduced to its lowest terms, the symbol of hydrochloric acid is obviously capable of division into 2 equivalents of $\text{H}'\text{Cl}'$, so that in reality 2 atoms of hydrochloric acid are required to represent 1 atom of water, the reason being that in the latter case the separable equivalents of hydrogen are held together by the indivisible oxygen. But, on the other hand, we may represent common salt and other similar bodies as analogues of the double atom of hydrogen. If in water we suppose the atom of oxygen to be replaced by hydrogen, we get the formula $\left\{ \begin{smallmatrix} \text{H}' \\ \text{H}' \end{smallmatrix} \right\} \text{H}'$ precisely analogous to $\left\{ \begin{smallmatrix} \text{H}' \\ \text{H}' \end{smallmatrix} \right\} \text{Cl}'$ and $\left\{ \begin{smallmatrix} \text{K}' \\ \text{K}' \end{smallmatrix} \right\} \text{Cl}'$; and as each of these last ones splits itself into 2 equivalents of chloride, $\text{H}'\text{Cl}'$ or $\text{K}'\text{Cl}'$, so does the other separate into 2 equivalents of hydride, $\text{H}'\text{H}'$, any further division being opposed by the antipolar relations of the atoms. This explains how it is that in salts we not unfrequently find such compounds as KCl substituted for the hydrogen, as seen below:



According to the above table, the salts on the right hand column are considered as oxides or sulphides of independent self-existing compounds, and I believe that such is really a correct mode of representing them; the second instance is, perhaps, more liable to exception than the others. My object, however, is rather to show how a very large number of bodies may be looked upon from a single point of view, than to prove that in every instance this point of view is necessarily the best one from which each particular object can be regarded.

To advert briefly to some of the most important advantages accruing from this view of the constitution of salts, and, in the first place, to its almost unlimited applicability. By the adoption of an extremely simple type, bodies of the most different properties are brought together under a common formula; such is its comprehensiveness, that salts previously considered most heterodox in their composition are included with as much facility as are their more normal congeners.

It comprises equally well the compounds derived from organic and from inorganic chemical action, and assimilates them to one another in a most marked degree.

If it complicates the formulæ of a few salts, it simplifies the representation of very many, as seen particularly in the cases of the citrates, the alums, and sulphates; its few complications, moreover, are rather apparent than real, and would obtain to nearly an equal degree in the old modes of writing, were the atom of hydrogen and its analogues doubled.

The type being neutral in composition, it follows that all the various substances formed on that type are likewise neutral in composition; a consideration of some importance as illustrating the simple deductions which proceed from the view. It explains clearly the mode of formation of normal salts. It used to be considered a strong argument in favour of the binary theory of salts, that it accounted satisfactorily for the well-known fact, that when an atom of base united with a monobasic acid to form a normal salt, it invariably required as many atoms of acid as itself contained atoms of oxygen; but by representing salts, in accordance with the above-detailed views, as substitution-products, more especially when the exponential notation is adopted, this fact will be better explained than even by the binary theory, and will then appear as a particular illustration of a general law, and as a necessary consequence of the substitutions connected with the formation of the salt: thus

$\left. \begin{smallmatrix} K' \\ K' \end{smallmatrix} \right\} O$, K having a single representative value, is replaced

by 1 atom of $N O_2$ to form the salt, $\left. \begin{smallmatrix} N O'_2 \\ K' \end{smallmatrix} \right\}^2 O$,

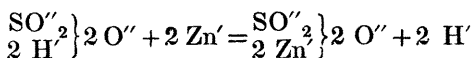
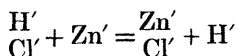
$\left. \begin{smallmatrix} Sn'' \\ Sn'' \end{smallmatrix} \right\} O_2$, Sn having here a double representative value, is

replaced by 2 atoms of $N O'_2$ to form the salt $\left. \begin{smallmatrix} 2 N O'_2 \\ Sn'' \end{smallmatrix} \right\}^2 O_2'$

$\left. \begin{smallmatrix} Bi''' \\ Bi''' \end{smallmatrix} \right\} O_3$, Bi having a treble representative value, is replaced by

3 atoms of $N O_2$ to form the salt $\left. \begin{smallmatrix} 3 N O'_2 \\ Bi''' \end{smallmatrix} \right\}^2 O_3$, and so on.

In common with the binary theory, it accords but one explanation of the ordinary action of easily oxydizable metals upon acid solutions, thus:



the result at any rate being that the zinc in each case simply replaces the hydrogen.

And lastly, these formulæ are quite in accordance with the atomic theory, in which respect they differ most remarkably from Gerhardt's. By establishing a difference to the eye between the atom of a body and its equivalent or substitution value, we gain a clearer idea of the precise meaning of these respective terms. Thus the atom of bismuth is marked with three dashes, Bi''' , to indicate that the atom of bismuth replaces or is equivalent to three atoms of hydrogen, and so on. Gerhardt, on the other hand, writes

$\left. \begin{smallmatrix} bi \\ Cl \end{smallmatrix} \right\}$ in which bi is supposed to be $\frac{1}{3}$ of Bi.

Such then are my reasons for applying the substitution formulæ to the inorganic chemical products. I do not consider it at all necessary to the integrity of these views, that the subordinate compounds indicated in the formulæ should in all cases be considered to have an actual, much more an independent existence. I make use of them only as representing, among the many possible arrangements of the elements, the ones which I consider illustrate the most probable action of the affinities concurring in the production of the salt. Even were it otherwise, however, I do not think that

those chemists who consider silicate of soda to contain ready formed the compound Si O_4 (NaSiO_4) and that the three phosphoric acids contain respectively such different, and out-of-the-way compounds, as P O_6 , P O_7 , and P O_8 , need demur at such simple subordinate compounds as I have ventured to introduce.
