

The following Table shows the progress and present state of the Society with respect to the number of Fellows :—

|                     | Patron<br>and<br>Honorary. | Foreign. | Having<br>com-<br>pounded. | Paying<br>£2 12s.<br>annually. | Paying<br>£4<br>annually. | Total. |
|---------------------|----------------------------|----------|----------------------------|--------------------------------|---------------------------|--------|
| November 30, 1863.  | 6                          | 49       | 324                        | 4                              | 274                       | 657    |
| Since compounded..  | .....                      | .....    | +3                         | .....                          | —3                        |        |
| Since elected ..... | .....                      | +3       | +4                         | .....                          | +11                       | +18    |
| Since deceased .... | .....                      | —2       | —11                        | —1                             | —6                        | —20    |
| November 30, 1864.  | 6                          | 50       | 320                        | 3                              | 276                       | 655    |

*December 8, 1864.*

Dr. WILLIAM ALLEN MILLER, Treasurer and Vice-President,  
in the Chair.

It was announced from the Chair that the President had appointed the following Members of the Council to be Vice-Presidents :—

The Treasurer.

Mr. Gassiot.

Sir Henry Holland.

The following communications were read :—

1. “Researches on certain Ethylphosphates.” By ARTHUR HERBERT CHURCH, M.A. Oxon., Professor of Chemistry, Royal Agricultural College, Cirencester. Communicated by A. W. HOFMANN, Ph.D., LL.D. Received October 21, 1864.

The constitution, properties, and derivatives of the so-called conjugated sulphurous and sulphuric acids have been made the subject of numerous researches, and have led, in the hands of Gerhardt and others, to very interesting results. I have examined at different times\* several members

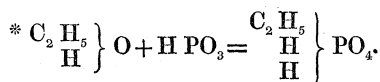
\* On the Benzole Series, Parts 1 & 2. Phil. Mag. April and June 1855.

On the Spontaneous Decomposition of certain Sulphomethylates. Phil. Mag. July 1855.

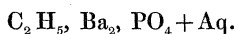
On the Action of Water upon certain Sulphomethylates. Phil. Mag. Jan. 1856.  
On Parabenzole, Parts 1 & 2. Phil. Mag. June 1857, and Dec. 1859.

of the methylsulphuric, phenylsulphurous, nitrophenylsulphous and other series, but have lately turned my attention to the analogous compounds of the phosphoric series. Some remarkable substances have been thus made, their constitution seeming to have a direct bearing upon the important question of the atomicity and equivalency of certain of the metallic elements.

Several substances might have served as starting-points for these new inquiries. A curious compound, phenylphosphoric acid,  $C_6H_5H_2PO_4$ , was prepared; but its instability, and the oxidation to which it and its salts are liable, rendered it unsuited for the present purpose. I intend to describe in the present paper but one series of salts, formed from Pelouze's ethylphosphoric acid,  $C_2H_5H_2PO_4$ . This compound, containing two atoms of easily replaceable hydrogen, appeared admirably adapted for the purpose in view. It is readily prepared by digesting (for 48 hours) finely crushed glacial phosphoric acid with alcohol of 90 per cent. :—



From the ethylphosphoric acid thus formed the barium salt was prepared in large quantity and of perfect purity. This compound,  $C_2H_5, Ba_2, PO_4 + 6H_2O$ , is remarkable for being less soluble in boiling water than in water at  $70^\circ C.$ , or even at  $15^\circ$ —a characteristic property of several other ethylphosphates. Boiling water, in fact, affects this barium salt in a peculiar manner. If to its boiling saturated solution a quantity of the ordinary crystallized salt be added, the crystals instantly assume a pearly aspect, and are found, after having been filtered off, washed once with boiling water, and dried *in vacuo* over sulphuric acid, to have lost  $5H_2O$ , and thus to have the formula



They thus contain the proportion of water found in the majority of the ethylphosphates. When, on the other hand, cold water is poured on these crystals, or on the salt dried at  $100^\circ$ , the lost water is regained, the nacreous aspect of the dried salt disappears, while a great increase in its bulk occurs.

From the barium salt the lead and silver compounds are readily made. To a solution of ethylphosphate of barium nearly saturated at  $70^\circ$ , acetate of lead or nitrate of silver is added in slight excess, the liquid allowed to cool and then filtered. The collected precipitate is to be washed with cold water. The lead salt may be obtained anhydrous by heating it to  $130^\circ$ – $150^\circ$ : it is almost insoluble in cold water, but is slightly soluble in hot water, from which it may be crystallized. The silver salt dissolves to some extent in hot water, and separates in pearly plates as the liquid cools. It is blackened, especially when moist, on exposure to daylight. Dried in

\* The following are the atomic weights adopted :— $C=12$ ,  $O=16$ ,  $Hg=200$ ; I have provisionally retained for  $Ag$ ,  $Ba$ ,  $Pb$ , &c. the lower atomic weights till lately in general use.

the water-oven, it retains one atom of water of crystallization, and has the formula  $C_2H_5Ag_2PO_4 + Aq$ . It was chiefly by double decomposition with the barium, lead, and silver salts that the compounds presently to be described were formed. The perfect purity of the substances used was established by rigorous experiment; a silver-determination, for instance, in the argentic ethylphosphate used in many of the reactions to be detailed further on, gave the following numbers:—

10·27 grains of the salt dried at  $100^\circ C$ . gave 8·22 grains of  $AgCl$ .

This result corresponds to 60·24 per cent of  $Ag$ , while the percentage required by the formula  $C_2H_5Ag_2PO_4 + Aq$  is 60·33. The other analyses were equally satisfactory.

I give, in the present communication, a selection of the most interesting of the numerous results obtained during the course of my experimental inquiry. Many points of departure for other researches have occurred—the investigation, for example, of the products, volatile and fixed, of the destructive distillation of the ethylphosphates, and the determination of the varying amount of water of crystallization in several of the salts prepared. I may cite the barium salts as illustrations. Not only do the salts already mentioned exist, namely one containing 6  $Aq$  and the other 1  $Aq$ , but a third compound may be obtained by evaporating at about  $50^\circ$  or  $60^\circ C$ . a saturated solution of the ordinary barium salt, and filtering off the deposited crystals rapidly. The slender pearly plates thus formed are perfectly definite and constant in composition; they probably consist of equal equivalents of the two former salts. Analysis gave the following numbers:—

7·04 grains gave 5·01 grains of  $Ba_2SO_4$ .

12·88 grains lost at  $130^\circ C$ . 2·5 grains of  $H_2O$ .

These results correspond to 41·85 per cent. of  $Ba$ , and 19·407 per cent. of  $H_2O$ ; the formula  $2(C_2H_5Ba_2PO_4) + 7Aq$  demands 42·28 per cent. of  $Ba$ , and 19·44 per cent. of  $H_2O$ .

*Ferric Ethylphosphate*.—Equivalent proportions of argentic ethylphosphate and pure crystallized anhydrous ferric chloride were weighed out. The silver salt was mixed with some quantity of hot water, and the ferric chloride, previously dissolved in hot water, then added, the liquid being kept warm for some time. On filtering, a pale yellow liquid was obtained which contained no silver, and the merest trace of chlorine. On heating this liquid to the boiling-point, pale straw-yellow films separated from it: a quantity of these was collected, washed with cold water and with alcohol, and, after having been dried in the water-oven, analyzed with the following results:—

I. 6115 grm. of the ferric salt gave on combustion with chromate of lead 296 grm. of  $CO_2$  and 22 grm. of  $H_2O$ .

II. 475 grm. gave 142 grm. of  $Fe_4O_3$ .

III. 393 grm. gave 115 grm. of  $Fe_4O_3$ .

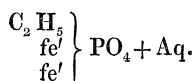
IV. 475 grm. gave 294 grm. of  $Mg_4P_2O_7$ .

V. 1317 grm. lost at  $150^\circ C$ . 134 grm. of  $H_2O$ .

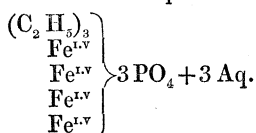
These numbers correspond to the formula  $(C_2 H_5)_3 Fe_4 3 PO_4 + 3 Aq$ , as may be seen in the comparison given below of the theoretical and experimental percentages.

|          |      | Theory. |        | Experiment. |       |       |       |
|----------|------|---------|--------|-------------|-------|-------|-------|
|          |      |         |        | I.          | II.   | III.  | IV.   |
| $C_6$    | .... | 72      | 13.38  | 13.19       | —     | —     | —     |
| $H_{21}$ | .... | 21      | 3.91   | 3.92        | —     | —     | —     |
| $Fe_4$   | .... | 112     | 20.82  | —           | 20.82 | 20.56 | —     |
| $P_3$    | .... | 93      | 17.28  | —           | —     | —     | 17.28 |
| $O_{15}$ | .... | 240     | 44.61  | —           | —     | —     | —     |
|          |      | 538     | 100.00 |             |       |       |       |

In analysis V. 10.17 per cent. of water were lost by drying the air-dried salt at  $150^\circ$ : the formula above given requires 10.03 per cent. If we allow the formula  $fe Cl$  to express the molecule of ferric chloride, giving to the iron in it the atomic weight  $\frac{28 \times 2}{3} = 18.67$ , then the ferric ethylphosphate may be written



Few chemists would now admit such an expression to be anything more than what may be termed an *equivalent* formula, comparable with that of ethylphosphoric acid itself, yet representing one-third only of the true atomic weight of the iron compound. It may, however, be worth while to consider whether there be any mode of arriving at a decision concerning the formula of the ferric ethylphosphate—whether the above simple expression be admissible, or the more complex form

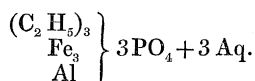


It appeared to me that, if the latter expression be the true one, we ought to be able to replace  $\frac{1}{4}$ th or  $\frac{3}{4}$ ths of the iron present by another metal: if the simpler formula be correct, then any other replacement but that of  $\frac{1}{2}$  would be impossible, unless indeed we suppose that the very chemical process made use of to effect the replacement causes a coalescence of three atoms of the original salt, in order that one more complex atom of the new mixed compound may be thereby constructed.

With this object in view, several experiments were devised. A solution saturated at  $60^\circ$  and containing a known proportion of ferric and aluminic ethylphosphates was brought to the boiling-point, and the salt thus separated removed by filtration. In other cases absolute alcohol was added to the warm concentrated solution till a part only, often but a small part, of the salt was precipitated. By these methods, and by the action of

mixed ferric and aluminic chlorides upon argentic ethylphosphate, several salts were obtained of constant as well as of definite composition. For in the majority of experiments where the same or slightly varied proportions were employed, the same compound was obtained, even where but a very small portion of the new compound, compared with the quantity formed, was allowed to separate or be precipitated. This observation applies to the salts obtained by ebullition and evaporation, by precipitation with alcohol, and by the action of the mixed ferric and aluminic chlorides upon the argentic ethylphosphate.

When the proportion of aluminium to iron in the mixed ethylphosphates ranged near the ratio 13·7 : 84, the salt first formed gave on analysis results corresponding to the formula



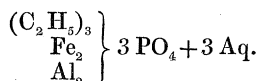
In an analysis where both Al and Fe were determined, the following results were obtained :—

1·056 grm. gave ·241 grm.  $\text{Fe}_4\text{O}_3$ , and ·0515 grm.  $\text{Al}_4\text{O}_3$ .

A comparison of these results with theory gives—

|                          | Theory. | Experiment. |
|--------------------------|---------|-------------|
| Percentage of Fe . . . . | 16·04   | 15·97       |
| Percentage of Al . . . . | 2·62    | 2·51        |

When the ratio 27·4 : 56 was attained, there was no difficulty in obtaining a salt having the formula



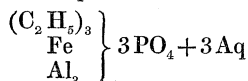
In one analysis

·83 grm. gave ·1305 grm.  $\text{Fe}_4\text{O}_3$ , and ·081 grm.  $\text{Al}_4\text{O}_3$ .

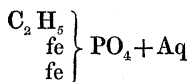
A comparison of these results with theory gives—

|                          | Theory. | Experiment. |
|--------------------------|---------|-------------|
| Percentage of Fe . . . . | 11·18   | 11·01       |
| Percentage of Al . . . . | 5·38    | 5·21        |

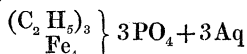
But on further increasing the proportion of aluminium to iron up to 41·1 : 28, no other definite compound could be obtained, though the salt



might be reasonably supposed to exist. Yet the two compounds obtained, if from their constancy of composition when prepared in diverse manners (volumetric determinations of iron in both salts were made with nearly the same results as those just given) I am justified in deeming them definite salts, not mixtures, may lead one to conclude the formula for the ferric ethylphosphate

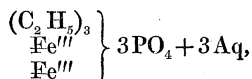


inadmissible, and the expression

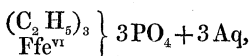


correct, since we can replace not half only of its iron, but one-fourth also by aluminium—a replacement manifestly impossible with the simpler expression. I am submitting this matter to further scrutiny by an investigation of the mineral phosphates containing not only aluminium and iron, but also calcium &c.

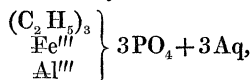
The higher atomic weights of iron still remain to be considered in connexion with these complex salts. If the atom of ferricum be triatomic and therefore =56, then the normal ferric ethylphosphate already described is readily represented thus,



a compound which equally well admits the expression



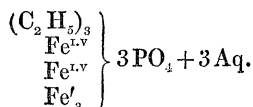
where Ffe=112. But with the mixed ferric-aluminic ethylphosphates the case is altered. The compound  $(\text{C}_2\text{H}_5)_3\text{Al}_2\text{Fe}_3\text{3PO}_4 + 3\text{Aq}$  allows us indeed to assume the triatomicity of ferricum and aluminium,



though excluding the supposed hexatomic value of these metals; while the other salt described,  $(\text{C}_2\text{H}_5)_3\text{Fe}_3\text{Al}_3\text{3PO}_4 + 3\text{Aq}$ , does not allow their triatomicity even; we return in fact to the oldest view, where Fe=28, and is sesquiatomic.

*Ferroso-ferric Ethylphosphate*.—By acting upon a warm saturated solution of basic ethylphosphate with a solution of mixed ferrous and ferric sulphates, filtering rapidly, and adding to the filtrate strong alcohol till a precipitate begins to separate, a solution is obtained which, after filtration and standing, soon deposits a greenish-white precipitate, slightly crystalline. This salt is constant in composition when prepared under rather widely varied conditions; but if in its preparation the ferric salt preponderate, the normal ferric ethylphosphate will be first precipitated. Perhaps a better way of preparing the new compound than that above given consists in warming a strong solution of ethylphosphoric acid with ferrous hydrate, filtering and adding strong alcohol. The precipitate produced by either method is to be washed with weak alcohol, and dried as rapidly as possible *in vacuo* over sulphuric acid. It contains iron in both conditions, and

gave results, according to the subjoined analytical details, agreeing with the formula



An identical compound may also be obtained by following the several plans adopted in preparing the ferric ethylphosphate; it is, however, very difficult to prevent a partial oxidation of the ferrosium in the salt. It will be noted that the atomic weight 28 is indicated by the constitution of this compound.

In order to analyze the ferroso-ferric ethylphosphate, the following methods were adopted. In a preliminary examination of the salt it was found that strong mineral acids did not effect the separation of phosphoric acid from it: it was also seen that its acid solution gave the ordinary reactions of both conditions of iron. For analysis a weighed amount of the salt was dissolved in dilute sulphuric acid, and the amount of standard permanganate solution decolorized by it ascertained; this gave the amount of ferrosium in the salt taken. A second experiment was then made, in which the total amount of iron in both forms was determined by permanganate after reduction of the sulphuric solution with pure zinc; the difference between the two percentage results gave the percentage of iron existing as ferricum in the original compound. The numbers thus obtained were on the whole satisfactory; the total amount of iron agreed nearly with that demanded by theory, though the amount of ferrosium in the salt was never less than .5 per cent. below the required proportion. It was in fact impossible entirely to prevent oxidation of the salt; but it will be perceived that the ferric oxide thus produced, not being lost, introduced but an inconsiderable error into the determinations. Nor did any inconvenience arise from the presence of phosphovinic acid, which, curiously enough, was found to be without reducing action on the permanganate, even in the presence of sulphuric acid. The following results were obtained in the analysis of the ferroso-ferric ethylphosphate.

The ferroso-ferric ethylphosphate was dried *in vacuo* over sulphuric acid. In each experiment with the permanganate solution .5 gramme of the iron salt was taken. Each cubic centimetre of the permanganate solution corresponded to .00492 grm. of Fe. The following are the results obtained by this method of analysis, three different preparations of the ethylphosphate being used:—

|   |   |  |
|---|---|--|
| Before reduction of the ethylphosphate with zinc. | { | I. 14.4 cub. centims. permang. = .070848 Fe  |
|   |   | II. 14.2 cub. centims. permang. = .069864 Fe |
|   |   | III. 14.0 cub. centims. permang. = .06888 Fe |
|   |   | IV. 14.4 cub. centims. permang. = .070848 Fe |
| After reduction of the ethylphosphate             | { | V. 25.0 cub. centims. permang. = .123 Fe     |
|   |   | VI. 24.6 cub. centims. permang. = .121032 Fe |

The mean of the first four experiments gives 14·022 as the percentage amount of ferrous in the compound. The theory  $(C_2H_5)_3(Fe''')_2(Fe')_3 3PO_4 + 3Aq$  demands 14·841.

The mean of the last two experiments gives 24·402 as the total percentage of iron in the compound. The theoretical percentage is 24·745. If the experimental mean percentage of ferrous be deducted from the total mean percentage of iron arrived at by experiment, thus,  $24·402 - 14·022 = 10·38$ , the number arrived at gives the percentage of ferric in the compound; the formula above given requires 9·894 per cent.: thus the experimental percentage exceeds the theoretical by ·486 per cent.—a small error, considering the very great difficulties attending the manipulation of this easily oxidized salt.

*Uranyle Ethylphosphate.*—Some pure uranic oxide,  $U_4O_9$ , was prepared by repeatedly acting on uranic nitrate with alcohol, the pasty mixture being heated on a water-bath. When the separation of the oxide was complete, it was mixed at a temperature of about  $60^\circ$  or  $70^\circ$  with a weak solution of ethylphosphoric acid. After dilution with hot water and digestion, the solution was filtered and evaporated. As soon as the boiling-point was attained, the solution almost solidified from the separation of clear yellow gelatinous masses of the new salt. These were collected by filtration of the boiling liquid after a portion of the water had evaporated. Submitted to analysis, they gave results leading to the formula  $C_2H_5, U_4O_9, PO_4 + Aq$ . This uranic salt thus agrees in constitution with the inorganic uranic phosphates already known, and lends additional support to Péligot's Uranyle theory. The following list gives the formulæ of various uranylic phosphates, uranyle being represented by the expression  $U_2O$  :—

- $U_2O, H_2, PO_4 + Aq \dots \dots$  Monuranc phosphate.
- $2U_2O, H, PO_4 + 3Aq \}$
- $2U_2O, H, PO_4 + 4Aq \}$   $\dots \dots$  Diuranc phosphate.
- $3U_2O, PO_4 (?) \dots \dots \dots$  Triuranc phosphate.
- $2U_2O, Ca, PO_4 + 4Aq \dots \dots$  Diurano-calcic phosphate (lime-uranite).
- $C_2H_5, 2U_2O, PO_4 + Aq \dots$  Diurano-ethylphosphate.

This new uranic salt, like many other ethylphosphates, is less soluble in water at  $100^\circ$  than in water at  $60^\circ$  or  $70^\circ$ . It separates from its solutions in pale yellow flocks, which dry up in the water-oven into amorphous brittle masses of a bright lemon-yellow colour. Attempts to replace a portion of the uranyle in this salt by calcium and by silver led to no definite results. The following are the analyses of the uranylic ethylphosphate dried at  $100^\circ$  :

- I. ·517 grm. gave ·106 grm. of  $Co_2$  and ·0835 grm. of  $H_2O$ .
- II. ·375 grm. gave ·254 grm. of protosesquioxide of uranium,  $U_6O_4$ .
- III. ·3335 grm. gave ·226 grm. of  $U_6O_4$ .
- IV. ·6645 grm. gave ·1735 grm. of  $Mg_4P_2O_7$ .
- V. ·1 grm dried at  $100^\circ$  lost at  $150^\circ$  ·044 grm. of  $H_2O$ .

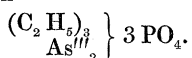
These results correspond to the following percentages :—



|                     |     | Theory. |        | Experiment. |       |       |      |
|---------------------|-----|---------|--------|-------------|-------|-------|------|
|                     |     |         |        | I.          | II.   | III.  | IV.  |
| C <sub>2</sub> .... | 24  | 5.79    |        | 5.59        | —     | —     | —    |
| H <sub>7</sub> .... | 7   | 1.69    |        | 1.79        | —     | —     | —    |
| U <sub>4</sub> .... | 240 | 57.97   |        | —           | 57.33 | 57.54 | —    |
| P <sub>1</sub> .... | 31  | 7.54    |        | —           | —     | —     | 7.29 |
| O <sub>7</sub> .... | 112 | 27.01   |        | —           | —     | —     | —    |
|                     |     | 414     | 100.00 |             |       |       |      |

The loss of water in analysis V. amounted to 4.4 per cent.; the theory C<sub>2</sub> H<sub>6</sub>, 2 U<sub>2</sub> O, PO<sub>4</sub> + Aq requires 4.35 per cent.

*Arsenious Ethylphosphate*.—The replacement of the basic hydrogen of ethylphosphoric acid by such an element as arsenic appeared to present some features of interest. The experiment was thus made. To a weighed quantity of pure arsenious chloride in a small flask, an equivalent quantity of anhydrous ethylphosphate of lead was added (in one experiment ethylphosphate of silver). The mixture became warm, and after moderate heating solidified. It was extracted with warm water, and the filtered extract evaporated. Beautiful feathery crystals separated in considerable quantity. Once crystallized from a solution, they appeared to dissolve less readily a second time in water. The cause of this phenomenon was soon discovered. Water gradually decomposes this salt, giving arsenious anhydride and ethylphosphoric acid. Although the analysis of the first crop of crystals was tolerably satisfactory, the original method of preparing the compound was abandoned, and another plan adopted. It was found that ethylphosphoric acid readily dissolves arsenious acid at the boiling-point, and that on heating and evaporating the solution, beautiful crystals of the arsenious ethylphosphate separate. In order to study this reaction more closely, the experiment was repeated, substituting, however, common orthophosphoric for the ethylphosphoric. The arsenious anhydride readily dissolved in considerable quantity on ebullition; and after filtration and cooling, an abundant crop of brilliant crystals was deposited from the filtrate. These crystals were not perceptibly affected by washing with cold water, and proved to be completely volatile when heated in a test-tube over a spirit-lamp. In fact they were nothing but octahedra of arsenious anhydride. Further experiments showed that it was not possible in this manner to form an arsenious phosphate; so that the statement in Gmelin's Handbook, referring to this salt as probably obtainable by the process above given, would seem to require correction. The normal arsenious phosphate, As PO<sub>4</sub>, remains to be discovered; a peculiar interest consequently attaches to the salt now under review, as the only arsenious phosphate known. Prepared by either of the processes above given, pressed between folds of filtered paper, and dried *in vacuo*, it gave on analysis numbers very nearly agreeing with the expression



The arsenic in the arsenious ethylphosphate was determined as sulphide, the precipitation being effected according to the directions given by Fresenius. The salt was dried by pressure between folds of filter-paper, it was then placed *in vacuo* over sulphuric acid, and finally heated for a short time in the water-oven. The arsenious sulphide obtained on its analysis was dried at 100° C.

I. 1.347 grm. gave .639 grm. of  $\text{As}_2\text{S}_3$ .

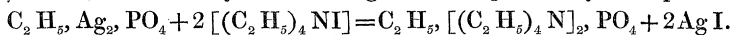
II. .591 grm. gave .29 grm. of  $\text{As}_2\text{S}_3$ .

The formula  $(\text{C}_2\text{H}_5)_3\text{As}_2\text{3PO}_4$  requires 28.74 per cent. of arsenic: analysis I. gave 28.95, while II. gave 29.58, the specimen of salt submitted to analysis in the latter case having been partially decomposed by washing, ethylphosphoric acid being thus removed, and consequently an excess of arsenious anhydride remaining in the residual salt.

The ease with which the arsenious ethylphosphate is formed induced me to hope that similar success would attend experiments made with another triatomic element, phosphorus. When an action is established between terchloride of phosphorus and ethylphosphate of silver, an oily product may be removed from the mass by means of anhydrous ether, but it yields on analysis results less definite than could be wished. Yet the reaction is a promising one: I hope to recur to it shortly, and to experiment in a similar manner with antimony and bismuth compounds.

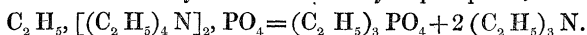
*Ditetrethylac Ethylphosphate.*—The ordinary ethylphosphate of ammonium is very readily made; its aqueous solution becomes acid on evaporation, but the salt may be obtained in a semicrystalline form by drying its saturated solution *in vacuo* over sulphuric acid. The salt heated carefully in an oil-bath for some time loses ammonia as well as water, but yet appears to yield, among other products, ethylphosphamic acid. A different and much more definite kind of decomposition takes place with the compound next to be described.

When a hot solution of argentic ethylphosphate is mixed with a solution of iodide of tetrethylum, a change occurs expressed by the equation

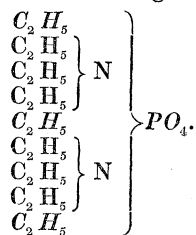


If the two salts be employed in the exact proportions indicated by this equation, it will be found that after boiling them together the new compound is contained in the filtrate. On evaporating this liquid first of all at 100°, and then *in vacuo* over sulphuric acid, a syrup, and finally a mass of confused crystals will be obtained; by long drying, these crystals lose their transparency, most probably because they have thus parted with some of their water of crystallization. The salt is intensely soluble in cold water, and deliquescent. The analyses of this salt were not exact, but corresponded sufficiently with the formula of an ethylphosphoric acid in which two atoms of hydrogen had been replaced by two atoms of tetrethylum. This view of its constitution is amply confirmed, not only by the mode in which the salt is prepared, but also by a singular decomposition

which it undergoes when heated. It begins indeed to decompose, though very slightly, at  $100^{\circ}$ , even when water is present, giving off a distinct odour of triethylamine. But on heating the salt itself to a temperature exceeding  $100^{\circ}$ , decomposition becomes more rapid, and the substance is finally resolved into triethylamine and triethylic phosphate,



The triethylamine was analytically identified by a platinum-determination in the double chloride made from it by addition of hydrochloric acid and platinic chloride. The metamorphosis of this ethylphosphate is perhaps more easily seen by means of the following arrangement of its formula:—



Several ethylphosphates have been prepared besides those described in the present paper; most of these salts, however, presented no marked features of interest. The ammonium, nickel, chromic, mercurous, and platinic compounds were investigated more particularly. The mercurous ethylphosphate is somewhat difficult to prepare; it is best made by adding a few drops of mercurous nitrate to a strong solution of potassic ethylphosphate, filtering off the grey precipitate first formed, and then adding a further quantity of the mercurous nitrate in solution; if the solutions are not too concentrated the salt gradually separates in pearly plates. Hot water partially dissolves this salt, the residue becoming yellow, and the solution acquiring a distinct acid reaction. It is slightly soluble in cold water, though not altogether without decomposition; it is insoluble in alcohol. Dissolved in dilute nitric acid and precipitated by chloride of sodium, the air-dried crystals of this salt gave the following result:—

·236 grm. gave ·191 grm. of  $Hg''Cl$ .

This corresponds to 71·09 per cent. of mercury; the formula  $C_2H_5Hg''_2PO_4 + 2Aq$  requires 71·45 per cent. The more probable formula,  $C_2H_5Hg''_2PO_4 + Aq$ , requires 73·82 per cent.

In offering the foregoing results to the Society, I do not wish it to be supposed that I consider them conclusive so far as regards the theoretical considerations introduced into the present paper. It is possible that the various aluminium and iron salts described may be mixtures only, in spite of their apparent constancy of composition; or, again, it may be that their formulæ ought to be doubled or quadrupled. Moreover the constitution of ethylphosphoric acid itself has not been made out: I trust that the study of diethyl-, ethylpyro-, and ethylmeta-phosphoric acids, and of the pro-

ducts of the action of heat on the ethylphosphates, may aid in determining this question. Meanwhile the observation, already recorded, as to the stability of ordinary ethylphosphoric acid and its salts in the presence of permanganate of potassium requires a word or two of further comment. When argentic diethylphosphate is acted upon with iodine, the silver and one atom of ethyl may be removed, and after treatment with finely divided silver and a little oxide of silver to remove any iodine and hydriodic acid, and then with excess of carbonate of barium, an ethylphosphate of barium is obtained, which, unlike the ordinary salt, immediately reduces permanganate of potassium; perhaps the ethyl in this salt exists in a different and less intimate form of combination. I am inclined to think that the permanganates will afford, in some cases, criteria for the detection of slight differences in isomeric compounds, although it would be premature at present to hazard an exact interpretation of the phenomena to which they give rise. I may add that treatment of an ethylphosphate with strong nitric acid fails to decompose the ethylphosphoric acid; so that phosphoric acid cannot thus be separated from this remarkably stable body.

II. "A Dynamical Theory of the Electromagnetic Field." By Professor J. CLERK MAXWELL, F.R.S. Received October 27, 1864.

(Abstract.)

The proposed Theory seeks for the origin of electromagnetic effects in the medium surrounding the electric or magnetic bodies, and assumes that they act on each other not immediately at a distance, but through the intervention of this medium.

The existence of the medium is assumed as probable, since the investigations of Optics have led philosophers to believe that in such a medium the propagation of light takes place.

The properties attributed to the medium in order to explain the propagation of light are—

1st. That the motion of one part communicates motion to the parts in its neighbourhood.

2nd. That this communication is not instantaneous but progressive, and depends on the elasticity of the medium as compared with its density.

The kind of motion attributed to the medium when transmitting light is that called transverse vibration.

An elastic medium capable of such motions must be also capable of a vast variety of other motions, and its elasticity may be called into play in other ways, some of which may be discoverable by their effects.

One phenomenon which seems to indicate the existence of other motions than those of light in the medium, is that discovered by Faraday, in which the plane of polarization of a ray of light is caused to rotate by the action