

sprue, down which considerable air was carried along with the metal. The result of the analysis leaves little doubt that the bottom, made of red bricks and fire-clay, was not thoroughly dry. The gases were collected over water, the ingot being immersed in an iron box, with a drill passing through a packing box into its side. The boring was done as rapidly as possible. This method of collecting the gases is not free from objections, but was the best at command. The average of two closely accordant analyses was as follows :

Carbonic oxide.....	2.08
Hydrogen.....	56.42
Nitrogen	39.36
Oxygen	2.14

A few of the cavities near the surface evidently communicated with the air, hence a little free oxygen, and a larger percentage of nitrogen.

The specific gravity of the solid steel, about one foot from the top of the ingot, was 7.866.

XVIII.—ON PEROXIDE OF HYDROGEN AND OZONE.

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[Second Paper.]

(With Figures on Plate I.)

Read April 1st, 1880.

1.—UPON THE RELATIVE AMOUNTS OF PEROXIDE OF HYDROGEN AND OZONE, OBTAINED IN THE OZONATION OF AIR BY MOIST PHOSPHORUS, AS DETERMINED BY THE METHOD OF DECOMPOSITION OF THESE BODIES, THROUGH THE AGENCY OF HEAT.

In preceding articles, and more especially in the first paper with the above title, it has been pointed out that both hydrogen peroxide and ozone are formed by the action of air upon moist phosphorus. Moreover, a number of experiments, protracted for several months (in which as many as 481 liters of purified air were used in a single experiment, and every devisable precaution was employed), were brought forward in support of the proposition that *the percentage of hydrogen peroxide in the ozonised air bears a constant ratio to that of the ozone*. The conclusion drawn from these results was, that the production of hydrogen peroxide, like that of ammonium nitrate, depends upon the same series of chemical changes as those which are

concerned, in this instance, in the generation of ozone itself. More over, that the connection between the production of the three bodies is a necessary one, and that any hypothesis which explains the generation of the ozone, and ignores the contemporaneous generation of hydrogen peroxide and ammonium nitrate, is of necessity imperfect, and, to a certain extent, erroneous.

The object of the present article is to demonstrate by a method entirely different from that previously employed :

I. That both hydrogen peroxide and ozone are generated by the action of air upon moist phosphorus.

II. That after very prolonged contact with one another, in a series of wash-bottles and desiccating tubes, both bodies survive in amounts capable of satisfactory estimation.

III. That when the current of ozonised air, containing hydrogen peroxide, is passed through a tube heated to various temperatures, the amount of water obtained by the decomposition of the hydrogen peroxide increases with the increment of temperature.

IV. That under these circumstances, the amount of the residual gas capable of decomposing a neutral solution of potassium iodide, regularly diminishes, and at 200° no such decomposition whatsoever occurs.

V. That after this point has been attained, if a solution of potassium iodide (entirely free from iodate) which has previously been acidified with sulphuric acid, be substituted for the neutral solution, it will undergo slow decomposition. This result is due, not to ozone, which is completely destroyed by continued exposure to a temperature of 200° , but to the spontaneous decomposition of an acidified solution of potassium iodide in presence of oxygen.

The objects kept prominently in view, in devising the method of the experiment, were :

1st. To bring filtered and purified air in contact with a large surface of phosphorus, the phosphorus being partly immersed in distilled water, quite free from ammoniacal and nitrous compounds, and maintained during the course of the experiment, at the temperature of maximum evolution of ozone ($24-25^{\circ}$ C.)

2d. To wash out of the ozonised air, as large an amount of hydrogen peroxide as possible, by an extended series of wash-bottles.

3d. To free the ozonised air, after its escape from the wash-bottles, from every trace of moisture.

4th. To decompose the hydrogen peroxide and ozone, at gradually increasing temperatures.

5th. To weigh any water, and to titrate any ozone, remaining after the ozonised air had been subjected to the action of heat.

These ideas were embodied in the arrangement of apparatus represented in the accompanying drawing (see Plate I). The train of purifiers, A, B, C, D, E, of which A was filled with the "absorbent hygroscopic cotton" (prepared according to von Bruhns), B and C, with glass beads drenched with soda solution, D and E, with sulphuric acid, was connected with the "phosphorus ozonator." The water in the jars of the ozonator was maintained throughout the course of all the experiments at 24–25° C. The ozonator was connected with a wash-bottle by means of kerite tubing, and the wash-bottle to four Geissler bulbs, F, G, H and I, the entire five being partly filled with water. The last bulb was connected with an empty wash-bottle, J, and this again with a wash-bottle, K, containing sulphuric acid. The drying was completed by three drying tubes, L, filled with beads drenched with sulphuric acid.

The entire length of these driers was $2\frac{1}{2}$ meters.

From the driers, the ozonised air passed into a curved glass tube, N, dipping down into an oil-bath, M. The middle portion of this tube for a length of 0.25 meter, was filled with amianthus, which had previously been ignited. The object of this amianthus filling, was to cause the ozonised air to filter through a great extent of heated air passages. After this followed a weighed sulphuric acid drying tube, P, a sulphuric acid guard tube, T, and a Geissler bulb containing a neutral solution of potassium iodide, W. Between P and T, an empty tube, S, closed with corks at both ends, was interposed, for convenience in slipping out the drying tube, P. All the connections were made either with strips of cotton cloth, bound tightly about the tubes with flower-wire and coated with melted paraffine applied with a brush, or by corks boiled in paraffine.

A number of preliminary experiments were tried, in order to determine whether on aspirating air only through the apparatus, the weighed drying tube, P, would change weight, or the potassium iodide solution would undergo decomposition. The former was found to be the case, a result attributed to the failure to detain all the moisture contained in the air before its reaching the tube, P. In these experiments, instead of the three drying tubes figured at L, but one was employed, having a length of 0.85 m. It was therefore supplemented by two more tubes, filled with phosphoric anhydride, and having together a length of 1.75 m.

This arrangement answered perfectly, so far as the detention of moisture was concerned, the drying tube, P, not altering in weight in repeated trials, when air alone was drawn through the apparatus. The oil-bath was then raised to a temperature of 200° , and the ozonator thrown into action. Six liters of air were drawn through the apparatus at this temperature, and six more at 150° . No change occurred in the potassium iodide solution in both experiments. This did not excite surprise, inasmuch as the complete decomposition at these temperatures of any ozone which might be present, was highly probable. But on repeating the trials, upon the same amounts of air at 100° and 22° , it was found, most unexpectedly, that the iodide solution did not change. There was no question as to the destruction of the ozone, during the course of its passage through the apparatus, inasmuch as it was plentifully evolved by the ozonator. Three ways of accounting for this decomposition were probable. Either the ozone was destroyed by the slow action of the hydrogen peroxide, generated simultaneously by the action of moist air upon phosphorus, or it was expended in acting upon the paraffine connections; or it was decomposed by the phosphoric anhydride. Since the arrangement of the apparatus differed only by the introduction of phosphoric anhydride from many similar arrangements hitherto employed in experimenting upon ozone, the last supposition appeared the one most probable.

On examining the anhydride, it was found to contain no uncombined phosphorus, but a notable amount of phosphorous anhydride, the raising of which to the highest stage of oxidation, had been the cause of the entire disappearance of the ozone.

The phosphoric anhydride in the drying tubes was therefore replaced by sulphuric acid, when it was found that the irregularities above noticed entirely disappeared.

Paraffine does not perfectly withstand the action of ozone, being slowly decomposed, with the formation of carbonic acid. In the course of long continued use, the paraffine joints employed by the author in connecting the ozonising elements of his large electrical ozoniser (*JOURNAL AMER. CHEM. SOC.*, I, 440), were destroyed, and had to be renewed from time to time. The amount of action on the joints was progressive, the paraffine connection between the first and second ozonising element requiring to be changed very seldom, while that between the eleventh and twelfth elements needed frequent removal. This increase of action demonstrated the effect of prolonging the time during which the same portion of oxygen was subjected to the influence of the silent discharge. In experimenting with

ozonised air, containing so small an amount of ozone as that employed in the investigation described in the present article, the connections may be made of paraffine without entailing serious error, but in researches of greater nicety, where not merely the relative but the absolute amounts of ozone have to be determined, paraffine connections cannot be employed.

The following experiments were performed under as nearly as possible identical conditions. Twelve liters of ozonised air were drawn through the apparatus in each experiment, at the rate of six liters per hour. The ozonator was maintained at the temperature of 24° C. The increase in weight of the drying tube, P, corresponded to the water formed by the decomposition of the hydrogen peroxide, when heated to the temperatures indicated in the table. The amounts of iodine set free in the potassium iodide solution are calculated into ozone according to the equations :



each molecule of ozone corresponding to two atoms of iodine. A large number of trials were made without throwing the ozonator into action, and it was only when the sulphuric acid drier, P, both at 0° and when the oil-bath was heated to 200°, became constant in weight, that the experiments recorded in the table were performed.

Table showing the relative amounts of hydrogen peroxide and ozone formed during the ozonation of air by moist phosphorus :

	Experiment.	Temperature.	Water.	H ₂ O ₂	Ozone.
1st Series.	{ I.	100°	0.0015 grm	0.0028 grm	Not determin.
	{ II.	50°	0.0010 "	0.0019 "	"
	{ III.	24°	0.0000 "	0.0000 "	"
2nd Series.	{ IV.	200°	0.0010 "	0.0019 "	0.0000 grm
	{ V.	200°	0.0011 "	0.0020 "	0.0000 "
	{ VI.	150°	0.0002 "	0.0004 "	0.0011 "
3rd Series.	{ VII.	100°	0.0015 "	0.0028 "	0.0013 "
	{ VIII.	50°	0.0003 "	0.0006 "	0.0044 "
	{ IX.	21°	0.0000 "	0.0000 "	0.0037 "
4th Series.	{ X.	200°	0.0018 "	0.0034 "	0.0000 "
	{ XI.	100°	0.0002 "	0.0004 "	0.0011 "
	{ XII.	22°	0.0000 "	0.0000 "	0.0051 "

These experiments, it appears to us, establish the truth of the first, second and fourth propositions. They show that *both* hydrogen peroxide and ozone are formed, and that on heating the ozonised air, the proportion of water thus produced regularly increases, while that of the ozone diminishes, until at 200° all the hydrogen peroxide is converted into water, and all the ozone into ordinary oxygen. At the close of the twelfth experiment, the immediate train of driers,

etc., was thrown out, and the Geissler bulb containing the potassium iodide solution, was connected directly with the first wash-bottle (that preceding F). The same volume of ozonised air, at the same rate, being drawn over under these conditions, gave a result corresponding to 7.94 mgrm, instead of 5.1 mgrm, as in experiment XII. In both experiments, the temperature of the ozonator was 24° , and of the iodide solution, 22° . The difference of 2.84 mgrm, which is 36 per cent. of the amount of ozone originally evolved, represents the loss due to the decomposition effected by the simultaneous presence of hydrogen peroxide.

This establishes the second proposition, and shows not only that peroxide of hydrogen and ozone can co-exist for a long time, in dilute condition, without great loss of either, but also that the amount of hydrogen peroxide in the ozonised gas, bears a not inconsiderable proportion to that of the ozone itself. In fact, neglecting the small amounts of hydrogen peroxide, which later on are shown to have been held back in the wash-water, the ratio of the hydrogen peroxide to the ozone exceeds one to three.

To determine the truth or falsity of proposition V.—“That the air, after being deprived of its hydrogen peroxide and ozone, could bring about a decomposition of an acidified solution of potassium iodide,” the experiment was again repeated with the tube N, maintained at a temperature of 200° . It will be noted that in every preceding trial at this temperature, a *neutral* solution of the iodide being used, *no liberation of iodine* occurred; but in this experiment, a decomposition took place corresponding to 0.21 mgrm of ozone. The increase in weight of the sulphuric acid drying tube, P, due to the decomposition of hydrogen peroxide, and the fixation of water, was 0.0022 grm. This experiment proves that the oxygen contained in a current of air, from which every trace of hydrogen peroxide and of ozone, has previously been removed by strong heating, may produce apparently the ozone reaction, *in case the potassium iodide solution used for titration has been acidified.*

It may be objected, although the objection is not supported by the above results, that even after passing through an amianthus plug 0.25 m. in length, maintained at the temperature of 200° , all the hydrogen peroxide had not been decomposed, and the residual peroxide had brought about the change noted. It may also be said that the result had been due to the use of potassium iodide, containing iodate. To show that a far simpler supposition accounts for the decomposition, the experiment was performed with air alone, and po-

tassium iodide, from which every trace of iodate had been removed, was used. To prepare by the method we have found most convenient* any amount of the crystallized iodide, absolutely free from traces of iodate, is so troublesome, that we preferred to employ a salt containing iodate, but from which the iodate had been carefully removed before using. This we attempted to do by throwing down the iodic acid with baryta, and then getting rid of the excess of baryta from the boiling solution by means of carbonic acid. But a notable amount of barytic iodate remained in solution. It was found better to saturate the neutral solution of potassium iodide, containing iodate, with hydrosulphuric acid, and then drive off the last traces of H_2S by heating. With this precaution, the potassium iodide sold as chemically pure, may be used in investigations similar to the foregoing.

20 c.c. of such a potassium iodide solution, containing 10 per cent. of iodide, was placed in one Geissler bulb, and the same amount slightly acidified, in another bulb, the two being connected together, and $4\frac{1}{2}$ liters of air drawn through them. At the expiration of $1\frac{1}{2}$ hours, the *neutral* solution was entirely *colorless*; the *acidified* solution contained 4.4 *mgrms of free iodine*.

This experiment points out too emphatically to need any comment, the magnitude of the error brought about by the use of acidified solutions in various titrations, and especially where it is used to estimate the ozone contained in a slowly moving current of ozonised air.

II.—AMOUNT OF HYDROGEN PEROXIDE ABSORBED BY THE WASH-WATERS.

In earlier experiments, undertaken first, to determine the relation between the temperature and volume of the ozone given off by the action of moist phosphorus upon air, and second, to estimate the amounts of by-products, the quantities of hydrogen peroxide had been determined in the wash-water only. This was done, after testing with metadiamidobenzole had established the absence of nitrous acid. In one series of experiments, the hydrogen peroxide thus determined, was the $\frac{1}{100}$ th part of the total weight of ozone evolved. Moreover, only the wash-water in the first wash-bottle was titrated, inasmuch as that in the bottles placed later in the series, contained too little hydrogen peroxide to permit of satisfactory estimation. But it was found by these later experiments, that this method gave a *much too low result for the relative percentage of hydrogen peroxide*, since the greater part of it was not held back by the wash-water.

*Contributions to the Chemistry of the Atmosphere, Ann. N. Y. Acad. Sci., 1

The bulb F, containing 47 c.c. of water, after evaporation to two-thirds its original volume, in order to expel any dissolved ozone, was found to contain 0.2 mgrm H_2O_2 . The bulb G, containing 26 c.c. of water, after being similarly evaporated, gave a reaction corresponding to 0.08 mgrm H_2O_2 . The bulb H, to 0.01 mgrm H_2O_2 . The falling off in the amount of hydrogen peroxide contained in F, in comparison with that in G, is perhaps greater than should be, for the reason that H and I were changed during the course of the experiments, and a much smaller volume of ozonised air passed through them, than through the two preceding bulbs. But the striking feature in the experiment is, that only 0.3 mgrm of H_2O_2 in all was absorbed by the wash-waters, the remainder passing on in the stream of ozonised air.

11.—UPON THE RELATIVE AMOUNTS OF HYDROGEN PEROXIDE AND OZONE.

The considerations above detailed, render manifest that the solution of this problem is attended with great difficulties. For the titration must be effected either in the neutral or acid solution of potassium iodide. In case the former is employed, there is no reason for supposing that any of the ozone itself escapes without decomposition. The statements which have been made to the contrary, have probably been based on the fact, that the potassium iodide solution has been employed to absorb a mixture of ozone and of hydrogen peroxide held in aerial suspension. And, moreover, the observation of von Babo has been lost sight of, that whenever ozone is decomposed by potassium iodide solution, hydrogen peroxide is set free. But the case is different with the hydrogen peroxide present in the ozonised gas. A very small portion of this undergoes absorption by a neutral solution of potassium iodide, as is strikingly shown by the following experiment. A Geissler bulb containing an 0.8 per cent solution of hydrogen peroxide, was connected with another bulb filled with a 10 per cent. solution of neutral potassium iodide, and 12 liters of air were aspirated through the two bulbs, the current flowing from the former through the latter. If the current of air merely decomposed a portion of the peroxide into water and free oxygen, no iodine would be liberated, inasmuch as oxygen alone is without action upon pure neutral potassium iodide. But, if any H_2O_2 were vaporised and carried over, it might be expected to act, although not energetically, upon the neutral solution. This latter supposition was the one which accorded best with the results of the experiment. The first bulb of the

Geissler apparatus became decidedly, the second bulb slightly, yellow. On titration, it was found that 0.02 mgrm of H_2O_2 had been absorbed.

What would occur if the titration of the ozonised gas were performed in an acidified solution of potassium iodide? In the first place, a decomposition would result from the action of the air alone, which would vitiate the results. In the second place, even an acid solution acts very slowly upon hydrogen peroxide, when the latter is present in extremely small amount. Thus, Schoene* has shown that it is only in somewhat concentrated solutions that the decomposition is complete after a short period. In a solution which contained in 1 liter nearly 1 grm H_2O_2 , 24 hours were required for the completion of the reaction. When about one-quarter grm H_2O_2 , in a liter, was present, it was not until after 30 hours that 98.2 per cent. of the total amount of hydrogen peroxide had been decomposed. With greater dilution, still less action ensued, and with only 5 mgrms H_2O_2 to the liter, after 48 hours, less than three-quarters of this amount had been decomposed.

IV.—PRODUCTION OF HYDROGEN PEROXIDE, DURING THE DECOMPOSITION OF POTASSIUM IODIDE BY OZONE, AND THE ORIGIN OF THE WHITE CLOUD FORMERLY THOUGHT TO INDICATE THE PRESENCE OF ANTOZONE.

One of the most singular phenomena connected with the action of moist phosphorus upon air, is the dense white cloud which makes its appearance *after* the ozonised air has issued from the potassium iodide solution. If this cloud is drawn over into an aspirator bottle, it gradually disappears on standing. The phenomena are of such a character that it is difficult to avoid framing the hypothesis, that we have to deal, not with one, but with two substances, one of which is absorbed by the potassium iodide solution, while the other passes on, and asserts itself by the production, in contact with water, of this mysterious white cloud. In fact, the hypothesis of the dual nature of active oxygen, the ozone and atmizone of Meissner, the ozone and antozone of Schoenbein, had come to be regarded as well established, and has only recently been overthrown. The credit of so doing is generally assigned to Nasse and Engler, who demonstrated that the so-called antozone, is merely hydrogen peroxide, diffused through a large quantity of aqueous vapor.† But this merit rather belongs, it

* Zeltschr. fuer analyt. Chemie, 18, 145.

† Ann. der Chim. und Pharm., 154, 230.

seems to me, to von Babo,* since his work hardly appears to have obtained the consideration which it deserves, and since some of his most important conclusions are, even at the present time, generally overlooked by writers upon this subject. I think it will be well to re-state them here. He says, "the formation of the cloud is always to be noted, when in any manner whatsoever ozone is decomposed, water being present. The clouds occur in the greatest intensity, when a portion of the ozone escapes decomposition, and this portion, as Meissner has quite correctly observed, acts in the dry condition upon the aqueous solution, in which it produces oxidation.

"Meissner believes that the clouds are not hydrogen peroxide, because this is not volatile, and therefore are due to a peculiar modification of oxygen (autozone).

"When ozonised oxygen acts upon oxidizable bodies, a reaction occurs for which we have many analogies. For instance, in the oxidation of a substance, not only is this body acted upon by the oxidizing agent, but in some instances, the operation of this agent extends to other bodies, which otherwise are not attacked. It may suffice to instance the oxidation of nitrogen in the burning of ammonia, or the solution of platinum, alloyed with silver, in nitric acid. Even so, ozone by itself does not act upon water, but oxidizes it when, at the same time, it acts upon other readily oxidizable bodies.

"In like manner, by its action upon potassium iodide, together with free iodine, potassium peroxide and potassium iodate, *hydrogen peroxide is formed.*" (The italics are the authors.) "When a dry current of ozone goes through a solution containing potassium iodide, the dry gas readily takes up vapor of water, which diffuses itself in the gaseous current, and thus, at least in part, becomes saturated with water vapor. By the action of the ozone, on the one hand, iodine is made free, and on the other hand, the vapor of water is oxidized. Along with these, a volatile combination of iodine and ozone may be formed. The formation of the hydrogen peroxide may be brought about by the oxidation of the fluid as well as of the gaseous water.

"Since, however, the hydrogen peroxide can only exist in the fluid condition, the portion which is formed in the gas condenses no fog vesicles, that is to say, a liquid suspended in the gas. This can swim for some time in the gas without decomposition, inasmuch as it finds itself in an atmosphere more or less saturated with water vapor, the

* Beitr. zur Kenntniss des Ozons. Ann. der Chem., Suppl. 1 and 2, 1863, 290.

reason of the rapid decomposition (the abstraction of water) not being present. How far such a cloud can be conducted through an apparatus, how difficultly condensible it is, is not surprising, when one reflects on the well-known behavior of other solid or fluid bodies suspended in gases. The destruction of the cloud, the so-called 'abklingen' of the atmizone, can happen in part through the gradual precipitation of the hydrogen peroxide, and in part through its decomposition, as when, for example, the gas is not sufficiently saturated with water vapor."

We believe that the theory advanced by von Babo is the correct one, and that it affords a satisfactory explanation of the phenomena associated with ozonation, whether the method by phosphorus, or by electrolysis, or by the silent discharge, be employed.

For when in the ozonation by phosphorus, the white clouds (of phosphoric anhydride and peroxide of hydrogen) which at first accompany the evolved gas, are completely absorbed by repeated washing with water, they make their appearance again *at the moment when* the ozone is decomposed by a potassium iodide solution. The phenomenon is a very striking one. The de-ozonised air, laden with the suspended hydrogen peroxide, thus generated, will present the appearance of a white cloud for a long time, even when absorption of the peroxide is slowly taking place at the surface of the water in the vessel into which the air has been aspirated.

Still more convincing are the phenomena attendant upon the ozonation by the silent discharge. To study these with more care, the following experiment was performed: perfectly pure and dry oxygen was ozonised by one of the "ozonising elements" (see JOURNAL AMER. CHEM. SOC., I, 441), and then drawn through three bulbs, the first containing solution of neutral potassium iodide, the second water, and the third chromic acid. The latter was connected with an aspirator. As soon as the strongly ozonised oxygen came into contact with the potassium iodide, a very slow current being employed, a yellow coloration made its appearance on the surface of the solution in the *first bulb*, and above the surface the characteristic white cloud. On increasing the rapidity of the current, this white cloud was drawn through the water and chromic acid, into the aspirator, and remained for one or more hours before its absorption was complete. After drawing over 6 liters of oxygen, containing 0.194 mgrm of ozone, the water was titrated, and found to have absorbed 0.31 mgrm of peroxide of hydrogen. The chromic acid solution was unaffected, showing that the suspended hydrogen peroxide may pass

through it without effecting a decomposition. The same remark applies to a neutral potassium iodide solution, put in the place of the chromic acid. The excessively dilute hydrogen peroxide held in a state of aerial aqueous suspension, was not able to decompose the neutral iodide during the course of the experiment. Of course, an *acidified* solution could not be employed to absorb the peroxide, since, as above shown, its decomposition occurs under the action of oxygen alone.

A final series of experiments was then tried with the following objects :

1st. To repeat the experiment of Andrews (R. Soc. Proc., 7, 475; Ann. der Chem. u. Pharm., 97, 371), and to determine whether the amount of ozone, as determined by titration, was precisely the same as that determined by weighing, with suitable precautions, the potassium iodide solution used for absorption, before and after the experiment. Also, to discover if possible, the sources of the anomalies observed by Andrews, when a neutral solution of iodide was employed.

2d. To establish whether, the same volume of oxygen being employed in two experiments performed under otherwise identical conditions, the amount of ozone as determined by the titration and weighing of an acidified solution of potassium iodide, would not be in excess of the amount as determined by the titration and weighing of a neutral solution.

3d. After drying the oxygen, on its leaving the potassium iodide solution, to find the amount of hydrogen peroxide, generated by the decomposition of the ozone in presence of water, and of an oxidizable body.

4th. To discover the alterations in composition which the potassium iodide solution, itself, had undergone ; to find out what proportion of the potash set free by the liberation of the iodine, had by a further process of oxidation, been converted into iodate, and in what condition the remainder was left, so that it was without action on the liberated iodine.

To perform these experiments, the apparatus employed above was modified by the introduction of a sulphuric acid drier, after the potassium iodide bulbs, and the drier was again protected by a guard from the latter part of the train. Before attaching the apparatus, similar to that shown in the wood-cut, for determining the hydrogen peroxide evolved from the potassium iodide bulb, the experiments included under the first head were performed :

First, with neutral solution of iodide.

The weights of the solution and the drier were carefully determined, before and after each experiment.

Amount of ozone, as found by increment of weight.	0.114	gm.
“ “ “ titration.....	0.108	“
	<hr/>	
Excess (as determined by weighing).....	0.006	“
2.75 liters of oxygen were drawn over in 2 hours and 40 minutes.		

Repeated.

Amount of ozone, as found by increment of weight.	0.0972	gm.
“ “ “ titration.....	0.0804	“
	<hr/>	
Excess (as determined by weighing).....	0.0168	“
2.75 liters of oxygen were drawn over in 3 hours.		

Second, with acidified solution of potassium iodide.

Amount of ozone, as found by increment of weight.	0.0768	gm.
“ “ “ titration.....	0.0798	“
	<hr/>	
Deficiency (as determined by weighing)....	0.0030	“
3.5 liters of oxygen were drawn over in 3 hours.		

Repeated.

Amount of ozone, as found by increment of weight.	0.0942	gm.
“ “ “ titration.....	0.1062	“
	<hr/>	
Deficiency (as determined by weighing).....	0.0120	“
3.25 liters of oxygen were drawn over in 3 hours.		

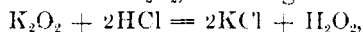
The first feature which strikes us in inspecting these results is, that the amounts of ozone as determined by weighing, are in excess when the neutral, and in deficiency when an acid, solution of potassium iodide was employed. This result was one which could have arisen from the presence of carbonic anhydride as an impurity in the ozonised oxygen. On interposing a bulb, containing barytic hydrate, before the iodide solution, the formation of a white precipitate showed that this impurity was actually present. It was not contained in the oxygen used, since this had been most carefully purified, but was formed by the action of the ozone on certain paraffine connections employed. The cause of the deficiency, when an acidified

solution of iodide was employed, is not so plain. Since the error due to the paraffine vitiated the results, the continuation of the experiments has been postponed until an apparatus constructed entirely of glass could be obtained.

But it was very evident that the white cloud formed when an acidified solution was employed in the titration, was more conspicuous than when a neutral solution was used. If we suppose, as von Babo states, that in addition to potassium iodate, potassium peroxide and hydrogen peroxide are formed at the same time, then the reaction in the neutral solution may be represented by the equation :

$$4KI + 2H_2O + 6O_3 = K_2O_2 + 2KIO_3 + I_2 + 3O_2 + 2H_2O_2,$$

and the decomposition of the K_2O_2 , according to the equation,



would result in additional liberation of hydrogen peroxide from the acidified solution.

Much has been written concerning the nature of the reaction which ensues when potassium iodide is decomposed by ozone, and the hypothesis of Schoebbein has found favor in some quarters, that while potash is formed and is present in the solution, the liberated iodine is protected from its action by the presence of a large excess of potassium iodide. The objections to this theory are, it appears to me, insuperable. In the first place, no excess of potassium iodide, however large, will prevent the combination of free potash with dissolved iodine. In the next place, if we take a potassium iodide solution which has been decomposed by ozone, and wash out all the liberated iodine by carbon disulphide, the colorless liquid remaining will not have the slightest alkaline reaction. Now, whether this neutral liquid contains potassium iodate alone, or this body, together with potassium peroxide, the result would be the same on the addition of acid; a fresh portion of the potassium iodide would be decomposed, with liberation of iodine. But a quantitative analysis showed that the amount of potassium combined as iodate, was not sufficient to account for all the iodine set free on acidifying. Hence, we believe that the explanation of von Babo is the correct one, and that, in addition to potassium iodate, small amounts of potassium peroxide and hydrogen peroxide are also formed.