parts. In passing round, the opening exposes regularly to solar influence different parts of the photographic paper,—the smallest part of the opening allowing the influence to be exerted for considerably less than a minute, whilst the largest part admits of the action of the sun's rays for more than an hour. The paper, by experiment, is so adjusted, that the greatest amount of actinic power darkens it completely during the shortest exposure, whilst the weak light of winter is just sufficient to produce the effect during the passage of the longest part of the opening. The degrees between these points become of course, under the ever-varying conditions of solar radiation, unequally darkened, and the paper being carefully marked to the hours of the day, it is quite easy to register *numerically* the varying effects produced. It will not therefore be necessary to have recourse to any plan of fixing the impressions made, which is always an uncertain process. It is hoped that by the next meeting of the Association the author will be enabled to furnish registers complete for twelve months, and he thinks he shall then be enabled to show that the actinic influence is one which must be taken into account in many inquiries, and to prove that the actinic or chemical power, and the phænomena of luminous and thermic action, are not found in any constant ratio in the solar rays, but that they are liable to continual variation.

On Ozone. *By* Professor SCHÖNBEIN *of Basle.*

THE British Association has done me the honour of inviting me to prepare a report on my researches regarding a peculiar agent to which I have given the name "Ozone." Flattering as such a charge must have proved to me, I undertake its execution with great diffidence, less on account of the subject of the report itself, than in consequence of my being obliged to make use of an idiom which I am not in the habit of speaking. Having fully experienced on former occasions the kindness of the same Association I have now the honour to address, I count upon your indulgence, and am convinced that you will receive with your wonted urbanity the very imperfect communication of a man who is certainly in one respect an alien to this country, but who feels himself nevertheless intimately connected with your land by many ties of friendship and scientific intercourse, and considers old hospitable England as his second home.

Were I not actuated by such feelings, I would not have ventured to come forward on this occasion, and it is to those feelings alone that I owe the courage requisite for a stranger who is to speak before an Association counting amongst its members the very essence of British philosophers. In taking the liberty to give you an account of the results obtained from researches with which I have been occupied these last six years, I shall chiefly keep in view the most novel facts I have been fortunate enough to ascertain, and I shall try to be as concise and clear as possible in stating them. Now and then, as the occasion occurs, I intend to enter into theoretical considerations and draw inferences from the phænomena observed. After having made you fully acquainted with the subject of my report, I need not say how much you will oblige me by making any observation or suggestion calculated to clear up a matter which I readily allow is yet very far from being thoroughly understood and sifted to the bottom. I shall feel myself fully repaid for the many pains I have taken these last five or six years in investigating the nature of the electrical smell, if I happen to succeed in convincing you that my subject is worthy of philosophical research and likely to open a new field

of inquiry. First of all permit me to state the reasons which induced me to undertake that series of investigations, the principal results of which will form the substance of my communication.

The peculiar smell developed during electrical discharges and the peculiar odour disengaged by lightning, have been the subject of a good deal of conjecture; but as far as I know, philosophers have not yet succeeded in clearing up the nature of that smell. The obscurity in which that phænomenon is enveloped, and the fact, I think first stated by myself, that on electrolysing water an odour makes its appearance very like to that called the electrical smell, excited my curiosity so much the more, that the circumstances under which the two sorts of smells are produced are apparently so very different from each other.

I made up my mind to investigate the subject as closely as possible, and in spite of its peculiar difficulty and many fruitless endeavours, I succeeded at last in ascertaining some facts which seemed to open a path for further and accurate inquiry.

These facts were,—1, that the odoriferous principle developed during the electrolysis of water is only disengaged at the positive electrode; 2, that the same principle may be preserved in well-closed bottles for any length of time; 3, that this principle polarizes negatively gold and platinum; 4, that the odoriferous substance is destroyed by heat and a number of oxidizable bodies; 5, that the electrical brush has the same odour as the oxygen disengaged at the positive electrode; 6, that the brush has the power of polarizing negatively gold and platinum; 7, that on heating the points out of which electricity is passing into the atmosphere, they no more develope the electrical smell. From these and some other facts, I was inclined to infer that the electrical brush produces the same principle which is disengaged at the positive electrode during the electrolysis of water, and as chlorine, with regard to its voltaic bearings, acts very similarly to this odoriferous principle, I suspected the latter to be a body analogous to chlorine. To decide on the correctness of that conjecture, there seemed to be no other way left open than to isolate the principle in question; but considering the infinitely small quantities in which the odoriferous substance is produced under the circumstances mentioned, the carrying into effect that isolation assumed the appearance of a thing lying beyond the reach of possibility. Yet after many trials undertaken with a view of producing more abundantly and by other than electrical means, my peculiar principle, I succeeded at last in doing so, and phosphorus proved to be the substance most convenient to obtain that end. And from the discovery of the most remarkable action which that body under certain circumstances exerts upon common air, I was led to ascertain the whole series of the curious and rather surprising facts I am about to state, and to arrive, if not at the complete solution of my problem, at least at the opening of the path which will ultimately lead to that goal.

And now I am touching upon that part of my report which, as to its matter of fact contents, is the more interesting one of the whole of the communication I have to make to you, and I beg leave to call your attention to the following statements:—

1. If at a temperature of 32° a piece of phosphorus, having a clear surface, be placed in a bottle filled with common air, a peculiar smell makes its appearance which is considered to be due to the vapour of phosphorus; at the same time that the included air assumes the power of polarizing positively a plate of platinum or gold which happens to be brought in contact with it.

2. Everything remaining in the state indicated, except the temperature being raised to about 60°, a change will very soon take place both with re-

gard to the smell of the air and the electro-motive power of the latter. The former will resemble the electrical smell, and the air will now be able to polarize negatively gold or platinum.

3. Atmospheric air completely deprived of its moisture and put in contact with phosphorus, does not give rise to the production of the electro-negative principle.

4. Atmospheric air, which contains only small quantities of the vapours of æther, alcohol, olefiant gas, sulphurous acid, nitrous acid, sulphuretted, phosphuretted or seleniuretted hydrogen, is not capable of developing the electrical smell, or assuming the state of the electro-negative polarity.

5. A mixture of oxygen and carbonic acid, or of oxygen and hydrogen, acts with regard to phosphorus like the common air, or an artificial mixture of oxygen and nitrogen.

6. Pure oxygen, or nitrogen, or hydrogen, or carbonic acid gas, whether moist or anhydrous, being placed in contact with phosphorus, becomes positively polarized; but none of those substances produce our electro-negative principle or the electrical smell.

7. To generalize the circumstances under which phosphorus is prevented from generating the said principle, it may be said that anything that stops the slow combustion or the emission of light of phosphorus at the common temperature, also renders impossible the development of the electrical smell, whilst the latter is always produced in an atmosphere in which phosphorus exhibits in the dark the phænomenon of a lively emission of light.

8. The positive polarity and alliaceous odour assumed at zero by common air in contact with phosphorus, is most likely due to the vapour of that body, whilst the negative polarity and the electrical smell developed at a higher temperature in the same air, originate in that peculiar principle, which, on account of its strong odour, I have called ozone.

As far as my experiments go they show that ozone enjoys the following properties:—

1. Stripes of blue litmus paper, being plunged into an ozonized atmosphere, are within a very short time completely bleached without being reddened in the least degree. Stripes of paper, having been coloured blue by a solution of indigo, and placed under the same circumstances, turn white. A solution of indigo or of litmus, being shaken with an ozonized air, loses also its colour exactly in the same way as if the solution had been treated by chlorine.

2. Most metals, silver even not excepted, being in a state of minute mechanical division and put in contact with ozone, almost instantaneously destroy that principle at the common temperature. Silver being changed under the circumstances into a compound containing nothing but metal and oxygen, it seems that the other metals are also oxidized by ozone.

3. Iodine put into an ozonized atmosphere is changed into iodic acid.

4. Powder of charcoal very rapidly destroys ozone.

5. Phosphorus quickly takes up ozone, being transformed into phosphoric acid.

6. Sulphuretted, seleniuretted, phosphuretted, carburetted, and iodurretted hydrogen rapidly destroy ozone, and are themselves decomposed by that principle.

7. Sulphurous acid and ozone being mixed together disappear and produce sulphuric acid.

8. Nitrous acid and ozone destroy each other with instantaneous quickness, producing nitric acid.

9. A number of metallic protoxides being put in contact with an ozonized

atmosphere are changed into peroxides. Solutions of the alkaline bases, as potash, soda, baryta, &c., take up rather slowly ozone, producing peroxides. The hydrates of the protoxides of manganese, lead, cobalt, nickel, or silver, being attached to stripes of paper and suspended in an ozonized atmosphere, are rather rapidly changed into the peroxides of those metals. Potash takes up ozone and water too.

10. A solution of iodide of potassium is rapidly decomposed by being treated with ozonized air, iodine being eliminated. At the same time iodate of potash is produced, which production is however preceded by the formation of a peculiar compound most likely consisting of iodide and peroxide of potassium. Hence it comes that paste of starch being mixed up with some iodide of potassium and exposed to ozonized air, instantaneously turns blue, and proves to be the most delicate test for ascertaining the presence of ozone.

11. Crystals of bromide of potassium, put into paste of starch and exposed to the action of ozone, colour that paste orange-yellow.

12. A solution of the yellow ferro-cyanide of potassium readily takes up ozone, yielding the red ferro-sesquicyanide.

13. The white cyanide of iron, being exposed to the action of an ozonized atmosphere, is instantaneously changed into the blue one.

14. The salts of the protoxides of iron and tin rapidly destroy ozone, and are transformed into peroxide salts.

15. A great number of metallic sulphurets, being put in contact with ozonized air, lose their colour and are changed into sulphates; a piece of paper having been written over with a solution of acetate of lead and blackened by sulphuretted hydrogen, rapidly turns white within ozonized air.

16. A number of organic substances, both of vegetable and animal origin, being placed within ozonized air, almost instantaneously destroy the odoriferous principle; for instance, saw-dust, straw, ulmin, vegetable mould, albumen, fibrine, caseous matter, and therefore blood, milk and common cheese.

17. If ozonized air be caused to pass through a narrow tube into the open air, that current, of course, produces all the chemical reactions before mentioned; but if part of the tube of emission is heated not quite red-hot, the peculiar smell of the current disappears at once, and along with it all the chemical and voltaic properties belonging to ozone. Its bleaching and polarizing power, its capability of decomposing iodide of potassium, &c., are gone.

18. Common air, being as richly as possible charged with ozone, has a smell resembling very much that of chlorine, bromine and iodine; but if ozone is much diluted with common air, its smell cannot be distinguished from that developed near points of electrical emission.

19. If common air, strongly charged with ozone, be inhaled only in moderate quantities, effects are produced similar to those caused by the respiration of chlorine, *i. e.* coughing, and an inflammation of the mucous membranes. Small animals put into richly ozonized air die very soon. I saw a mouse, which had been placed in a large bottle filled with strongly ozonized air, succumbing within the space of five minutes. As the quantity of the ozone which killed the animal must have been immeasurably small, it appears that this principle proves highly deleterious to the animal system.

20. Chemically pure water, being acidulated by pure sulphuric acid or phosphoric acid and electrolyzed, yields oxygen charged with the same principle, which is produced when phosphorus acts upon common air; for that oxygen enjoys all the properties belonging to ozone engendered by the agency of phosphorus. To obtain ozone by voltaic means, it is necessary that the acidulated water employed for that purpose be entirely free from any sub-

stance having a tendency to unite with oxygen or ozone, and that besides the temperature of the liquid to be electrolyzed be as low as possible. When the conditions indicated are fulfilled, the disengagement of ozone taking place at the positive electrode will last as long as the current continues to pass through the said liquid. Hence it follows that no production of ozone will take place if the electrodes consist of other metals than gold or platinum, or if the liquid to be electrolyzed contains small quantities of sulphuretted hydrogen, sulphurous acid, proto-sulphate of iron, æther, alcohol, &c. An aqueous solution of potash does not yield a trace of ozone, because free ozone is taken up by that solution.

21. The electrical brush developes, as is well known to philosophers, a peculiar odour which cannot, as I have already mentioned, be distinguished from that of diluted ozone, be that ozone produced by the agency of phosphorus or by the electrolysis of water. But the chemical and voltaic reactions exhibited by the electrical brush are also quite the same as those produced either by chemical or voltaic ozone. Platinum foil being exposed to the action of that brush assumes the state of negative polarity, a piece of litmus paper is bleached, iodide of potassium or hydro-iodic acid decomposed, iodine being eliminated, the ferro-cyanide of potassium transformed into the sesqui-cyanide, the hydrate of protoxide of lead changed into the brown peroxide, provided the substances mentioned be sufficiently long acted upon by the electrical brush. If only small quantities of sulphurous acid, nitrous acid, sulphuretted hydrogen, olefiant gas, or vapour of æther or alcohol are present in the air into which the electrical brush is passing, the latter does not develope the peculiar electrical smell, neither does it produce any of the chemical or voltaic reactions before mentioned. A point of electrical emission being heated not quite red-hot, yields a brush which has no smell whatsoever, has no polarizing or bleaching power, does not decompose iodide of potassium, &c.; but as soon as the point in question is suffered to cool down again below a certain degree of temperature, the peculiar smell reappears, and along with it we obtain again all the reactions peculiar to ozone. From these facts we are allowed I think to draw the inference, that the odoriferous principle disengaged by the electrical brush is identical with the odoriferous substance which is developed at the positive electrode during the electrolysis of water, and identical also with the electro-negative principle resulting from a peculiar action exerted by phosphorus upon the moist atmospheric air.

In order to ascertain the nature of that remarkable principle, I have tried a variety of methods with the view of procuring it in an isolated state, but all my endeavours made to that effect have hitherto failed, and I am not yet able to give quite a decisive answer to the question, What is ozone?

That principle being developed by phosphorus within a mixture of oxygen and nitrogen, but not in pure oxygen; having in many experiments obtained no ozone from electrolyzing water which had been boiled and deprived of its atmospheric air; producing the same principle within the atmosphere by the agency of common electricity; and considering the striking analogy which exists between ozone and chlorine; I was for a time induced to think the former to be an elementary substance forming a constituent part of azote, and to give up my first idea, according to which I considered ozone as a peculiar compound consisting of oxygen and hydrogen.

The impossibility of isolating the principle, and the fact that nothing but oxidizing effects could be obtained from making ozone to act upon a great number of substances, induced me to resume the first view I took of the subject in question, and to institute a series of experiments with the intention of ascertaining more accurately the conditions required for the formation of

ozone. In that inquiry I found that the presence of water is quite indispensable for engendering ozone, and that it is the more abundantly produced the larger the quantity of water which is put into contact both with phosphorus and common air. I likewise ascertained that no ozone is formed by phosphorus if free oxygen be excluded. Nitrogen may be replaced by carbonic acid or hydrogen without stopping the generation of ozone. Hence it follows that nitrogen has directly nothing to do with the production of ozone, and that the latter cannot be a constituent part of azote. From the fact that dry ozone passing along a heated tube is found to be destroyed, we must also infer that it is no elementary principle.

Now, taking together all the facts regarding both the circumstances under which ozone is formed and the chemical effects produced by that substance, we can hardly help admitting that the odoriferous principle is a compound consisting of oxygen and water. The experiments made independently of myself by my friend, the excellent and accurate chemist of Geneva, M. Marignac, and by M. de la Rive also, have led to results quite in accordance with the view I originally took of the nature of ozone. Marignac and De la Rive have ascertained that acidulated water, containing not the slightest trace either of free nitrogen or azotic matter, yields ozone as long as a voltaic current is made to pass through that liquid, provided however it be kept as cold as possible. M. Marignac has also found that mixtures of oxygen and hydrogen, or oxygen and carbonic acid gas, charged with aqueous vapour, produce ozone as well as a moist mixture of oxygen and azote. That able chemist has further ascertained that silver in a state of minute mechanical division readily takes up ozone, yielding nothing but a compound of silver and oxygen. Agreeably to my own experiments, M. Marignac has shown that ozone transforms iodide of potassium into iodate of potash.

Now these facts, combined with those ascertained by myself, seem to leave hardly any doubt about the nature of ozone, and confirm the view I took of it six years ago.

Thenard has made us acquainted with a compound consisting of one equivalent of water and one of oxygen. The question now is, whether the known peroxide of hydrogen be identical with my ozone. According to Thenard's own statements, peroxide of hydrogen has no odour, is soluble in water in any proportion, is less volatile than the latter, in decomposing itself it decomposes oxide of silver, reduces the peroxide of lead to a lower degree of oxidation, is not affected by iron, tin, or antimony, does not oxidize silver, but is decomposed by that metal, undergoes a spontaneous slow decomposition at the common temperature, and cannot exist at the boiling-point of water. The experiments of Becquerel and my own have shown that platinum, on being plunged into dilute oxygenized water, assumes the state of positive polarity. On the other hand, ozone has a strong and peculiar odour, is insoluble in water, exists, as far as we know, always in a gaseous state, readily oxidizes iron, tin, antimony, and even silver at the common temperature, changes the hydrates of the protoxides of lead and silver into the peroxides of those metals, seems not to be acted upon at all by gold or platinum, or the peroxides of lead and silver, and can bear a temperature considerably higher than that of boiling water without suffering decomposition; it seems to be stable at the common temperature, is decomposed not only by fibrine, but also by albumen, caseine and a variety of organic substances, and polarizes negatively gold or platinum. Now these facts seem to prove that ozone is different from peroxide of hydrogen. Whether the former contains more or less oxygen than the latter, or whether it is an isomeric modification of oxygenized water, can only be ascertained after having submitted isolated ozone

to analysis; I am however inclined to think that ozone will turn out to be a compound isomerical with peroxide of hydrogen, a conjecture which seems to be supported by the fact, that the odoriferous principle acts in so many cases the part of chlorine. On that subject however I shall speak hereafter. As to the production of ozone, we must, as far as our experiments go, account for it in the following manner:—Phosphorus, being placed under certain circumstances, enjoys the peculiar faculty to determine a chemical combination between oxygen and water. The same compound is produced in a secondary way on electrolyzing water; part of the oxygen, being in a nascent state and eliminated at the positive electrode, unites with water, and ozone, being insoluble in the latter liquid, is disengaged along with another part of oxygen that does not combine with water. It is possible that gold or platinum acting the part of the positive electrode may have something to do with the fact, that not the whole quantity of oxygen set free by the action of the current is united with water and transformed into ozone, for it may be that ozone being in a peculiar state (for instance, in the fluid state), happens to be decomposed by the metals mentioned just in the same way as common peroxide of hydrogen is.

Common electricity passing through atmospheric air acts upon that mixture like phosphorus, *i. e.* determines part of the atmospheric oxygen to unite with aqueous vapour to form ozone.

Before concluding the first part of my report, allow me to say a word or two about the well-known phænomenon which phosphorus exhibits when placed in moist atmospheric air. At the common temperature, and under the circumstances mentioned, that substance gives out in the dark rather a lively light, and is changed into a mixture of phosphoric and phosphorous acids. In dry atmospheric air scarcely any emission of light takes place, and in oxygen none at all. My experiments have invariably shown that no ozone is produced if phosphorus does not shine in the dark, and that the emission of light is the more lively the more richly common air or any other gaseous mixture happens to be charged with ozone. As phosphorus, like all other readily oxidizable substances, quickly takes up ozone at the common temperature, there can be entertained hardly any doubt that the shining of phosphorus which takes place within moist atmospheric air chiefly depends upon the reaction exerted by ozone on phosphorus, and that the oxidation of that substance is effected less by the free atmospheric oxygen than by the oxygen contained in ozone. By dint of some peculiar power, phosphorus determines, first, the formation of ozone out of the oxygen and aqueous vapour of the air; and so soon as this compound is generated, part of it begins to act upon phosphorus, and change the latter into acid, whilst another portion of ozone is dissipated into the surrounding air. If the bottle containing common air and a sufficient quantity of phosphorus happen to be completely closed, the production of ozone and its subsequent decomposition effected by phosphorus will continue so long as there is free oxygen present in the air; and we find therefore, after a certain time, in the bottle nothing but nitrogen and phosphatic acid. According to this view, the disappearance of the atmospheric oxygen is not due to the direct oxidation of phosphorus, but to the previous formation of ozone determined by that element, and to the subsequent decomposition likewise brought about by phosphorus. As to the cause of the emission of light alluded to, I am quite confident that it lies in the ozonization of phosphorus, if I am allowed to use that expression, that is to say, in the oxidation of phosphorus being effected by the agency of ozone.

The correctness of that explanation is put beyond a doubt, by the fact that

a number of gaseous substances being mixed with common air, phosphorus is prevented from shining in the dark. Gaseous, nitrous, or sulphurous acid, sulphuretted hydrogen, olefiant gas, hydro-iodic acid gas, vapour of æther, or alcohol, have this effect. Now according to the results of my experiments, all the substances mentioned instantaneously take up or destroy ozone, and such being the case, we can easily conceive why those gases and vapours present in the atmospheric air do not prevent phosphorus both from shining in the dark and from being changed into phosphatic acid. No ozone is or can be produced under those circumstances; for if that compound did ever happen to exist in that air, it would be instantaneously destroyed by the agents mentioned. Any gaseous substance therefore which readily unites with free ozone will prevent phosphorus from shining in that atmosphere, and of course also hinder the formation of ozone. Water being an indispensable ingredient for the generation of ozone, we can now easily see why in completely dry air the shining of phosphorus is nearly imperceptible. It is true, under these circumstances, some emission of light takes place, but it is exceedingly slight if compared to that exhibited in moist air. It is possible that that feeble phosphorescence results from a very small portion of oxygen directly uniting with phosphorus.

As ozone, in its action upon metals and a variety of other bodies, exhibits a very striking similarity to that which chlorine exerts upon the same substances, and as the remarkable analogy existing between these two principles extends itself even to the way of producing them, I shall take, on a future occasion, the liberty to submit to you some considerations regarding that subject, and bearing upon the two rival theories which have been founded with reference to chlorine.

On the part which Ozone acts in the Atmosphere.

Paste of starch, being mixed up with some chemically pure iodide of potassium and exposed for some time to the action of the open air, turns blue, whilst the same paste, shut up in a bottle filled with atmospheric air, remains colourless. Pieces of white linen, having been drenched with a solution of pure iodide of potassium, and left for some time in the open air, assume a brownish tint, which is due to iodine set free under the circumstances mentioned. That elimination of iodine does not, as far as my experiments go, take place in air inclosed within a bottle, though that air should contain even half its volume of carbonic acid gas. Iodide of potassium, after having for some time been exposed to the action of the open air, retains traces of a peculiar peroxide of potassium, of iodate and carbonate of potash, whilst in iodide of potassium kept in well-closed vessels nothing of the kind is found. From these facts it appears that the before-mentioned elimination of iodine, and the formation both of peroxide of potassium and iodate of potash, are not due to the action of free atmospheric oxygen nor to that of carbonic acid. According to my former experiments, air having been artificially ozonized, and made to pass through a solution of pure iodide of potassium, eliminates iodine, and causes the production of the said peroxide, iodate and carbonate of potash. Hence it follows that ozone produces, with the iodide of potassium, the same chemical changes as those which are effected by the open air, and between the two actions there is a difference of degree only and not of kind.

Now neither free oxygen, nor azote, nor carbonic acid being able to produce that effect, we must conclude that there is something peculiar in the atmosphere which causes the decomposition of our iodide, and has up to this present moment escaped the attention of chemists. But of what nature is

that oxidizing agent? My experiments have shown that during the electrical discharges which we effect by artificial means within atmospheric air, ozone makes its appearance, and from that fact we are allowed, I think, to draw the inference that ozone is also produced as often as the electrical equilibrium of the atmosphere suffers disturbance from natural causes. Now electrical discharges of that description continually taking place in that atmosphere, it follows that the odoriferous principle is continually formed there.

This conclusion, taken together with the before-mentioned fact, that iodide of potassium is changed by ozone exactly in the same way as it is by atmospheric air, renders it highly probable, if not altogether certain, that the peculiar oxidizing agent contained in our atmosphere is nothing but ozone produced by atmospheric electricity. Starting from that supposition, it is very easy to see why the freely circulating air only acts upon the iodide, and why stagnant or inclosed air does not. The quantity of ozone contained in a small volume of air must be exceedingly minute, and large quantities of air are therefore required to pass over a particle of iodide in order to cause a perceptible elimination of iodine.

If ozone is to be considered as a constituent part of our atmosphere, and it be a well-ascertained fact that ozone is capable of oxidizing a great number of substances at the common temperature, we can hardly help ascribing to that subtle agent many slow oxidations which are effected in the atmosphere. As electrical discharges take place not only during a thunderstorm, but daily and hourly, and as those discharges give rise to the production of ozone, that principle would by degrees accumulate to an alarming amount, and so as to endanger animal life, if nature had not taken care to remove it almost as quickly as it is formed. That removal is principally effected by the large quantities of organic matter which cover the surface of the earth, and which are suspended in the waters of the ocean.

Not one single elementary body, and very few oxidizable compounds, combine at the common temperature with free oxygen; oxidizable substances must be more or less heated in order to unite with that element. And it is a well-known fact, that oxygen, being in certain states of combination, is able to combine at the common temperature with a great variety of substances. Such being the case, we must be rather surprised at the facility with which organic substances, placed in contact with the atmosphere, are decomposed and transformed into carbonic acid and water, and that circumstance must strike us still more if we consider that carbon and hydrogen require high temperatures to be united with free oxygen. On account of the facts mentioned, it is rather difficult to admit that it is the gaseous oxygen of the atmosphere which combines with the carbon and hydrogen of organic matters. According to the statements I have made, ozone has the power to destroy all vegetable colours, and is taken up by a variety of organic substances. I think there can be hardly any doubt that the reactions mentioned are due to the oxygen of ozone being thrown upon the oxidizable constituent parts of vegetable and animal matter, and it is therefore very likely that atmospheric ozone acts some part in the slow decomposition which organic substances undergo in the open air, and that atmospheric ozone has also something to do with the common bleaching process. I however do not mean to say that the mentioned oxidations are exclusively to be ascribed to that ozone which is produced by the agency of atmospheric electricity.

We know that ozone may be produced in another than electrical manner, namely, by what the French call *action de présence*, or by the catalytic force of Berzelius. Phosphorus, in its action upon moist atmospheric air, exhibits the most interesting example of the kind, so that we may consider it as a

fundamental phænomenon which will best serve us to develope our ideas regarding the course of the slow oxidations which take place in the atmosphere.

Though phosphorus be one of the most readily oxidizable substances, it does not, to a perceptible degree, combine at the common temperature with the oxygen of atmospheric air, if the latter be completely deprived of its moisture. But no sooner has aqueous vapour been added to that air, than the oxidation of phosphorus begins, and along with it the emission of light and the production of ozone. Of that agent we know that it oxidizes readily at the common temperature even silver and iodine, and of course phosphorus too. Hence it appears that ozone, at the very moment of its being formed under the catalytic influence of phosphorus, out of atmospheric oxygen and water, reacts upon phosphorus, and causes both the formation of phosphatic acid and the emission of light.

Every chemist knows the fact that dry atmospheric air is not capable of oxidizing at the common temperature even the most oxidizable metals, and that under the same circumstances dry organic matters are not acted upon by anhydrous atmospheric air. Hence we conclude, that besides the atmospheric oxygen, water acts an important part in the slow oxidations which both the inorganic and organic substances undergo in the open air.

As far as I know, chemists entertain the opinion that in the cases mentioned water acts only a secondary part, that is to say, the part of a solvent for oxygen. It is supposed that the gaseous state of that body weakens considerably its affinity for the oxidizable substances, and it is said that the affinity is much increased by depriving oxygen of its gaseous condition, for instance, by dissolving that body in water.

As long as we had not been acquainted with the remarkable action exerted by phosphorus upon moist atmospheric air, the notions alluded to appeared to be plausible enough, and notably the rapid acidification which phosphorus at the common temperature undergoes in humid air could satisfactorily be accounted for in the way mentioned. But in the present state of science we can no longer keep up that view, and are obliged to admit that the slow combustion which phosphorus undergoes in damp air is principally, if not exclusively due to the exalted oxidizing power of ozone engendered by the catalytic force of phosphorus. Now if phosphorus enjoys the power of determining the atmospheric oxygen to unite with water into ozone, I think the conjecture is not over-bold which ascribes the same faculty to some other oxidizable substances. In this respect shining wood offers a very remarkable case. It is well known that the substance mentioned exhibits the slow combustion under circumstances very similar to those under which phosphorus undergoes the same change. Water being taken away both from atmospheric air and the rotten wood, that wood ceases to shine in the dark, and the formation of carbonic acid is also stopped. Now we cannot say that it is the want of water on account of which the oxidation of the wood is prevented, because out of the product of the slow combustion a protecting film is formed round the combustible matter, as might be said regarding phosphorus; carbonic acid, being a gaseous substance, leaves the wood as soon as it is produced. It seems not unlikely that the peculiar bearing of shining wood is due to the same cause to which phosphorus owes its remarkable properties, and if that conjecture is allowed to be made, we may go further, and admit the possibility that the organic substances which undergo a decomposition in the open air possess the power of producing ozone out of free oxygen and water, and that it is on this account that those substances require, besides oxygen, some water, in order to be resolved at the common temperature into carbonic acid and water.

Why that power is not enjoyed by uncombined carbon or hydrogen we know no more than we can as yet give a good reason for the fact that oxygen, being in a certain state of combination, is more apt to unite with oxidizable substances than uncombined oxygen. The phosphorescence of the sea, which never fails to strike with astonishment every man who witnesses for the first time that beautiful phænomenon, seems to originate in organic matter, which in a state of minute mechanical division is mixed up with the waters of the ocean. If I am not mistaken, one of the first-rate philosophical observers of the day, Ehrenberg, takes that view of the subject. The intensity of this phosphorescence is not everywhere the same; in the tropical climates the phænomenon is more brilliant than in the seas of the colder regions. It is also well known that the phosphorescence of the sea is intimately connected with the motion of its waters, or to speak more properly, that the phænomenon is dependent upon the particles of those waters being brought in immediate contact with the atmosphere. When a ship moves about, or the wind happens to agitate the sea, the surface of the brine is continually renewed, and consequently new particles of organic matter are every moment brought into contact with the surrounding air. As under these circumstances the phosphorescence is always called forth, the German philosopher has come to the conclusion that the phænomenon mentioned is principally due to an action exerted by the atmosphere upon the waters of the ocean, and ingeniously enough Ehrenberg considers that phosphorescence as the effect of a sort of respiration of the sea. If the waters of the ocean were found to contain phosphorus dissolved, nobody would doubt in the least that the phosphorescence in question depended upon the slow combustion of that substance taking place at the surface of the sea, and we could easily see why the motion of its waters, the temperature, &c., exert an influence upon the phænomenon. Now as we have got in shining wood an organic matter which, like phosphorus, undergoes the slow combustion in moist air, and as it is not unlikely that phosphorus and shining wood act in the same way upon atmospheric air, that is to say, that both substances produce ozone out of the oxygen and aqueous vapour of the atmosphere, it appears not improbable that there exist some other organic substances enjoying the property of shining in the dark. The organic matter occurring in the waters of the sea, and originating in the remains of a countless number of animal beings which are daily dying in the depths of the ocean, may very possibly enjoy that property, so much the more as that matter happens to be in a state of extremely minute mechanical division.

According to the conjecture suggested, we may consider that animal matter, with regard to its bearing to the atmosphere, as a representative either of phosphorus or shining wood, and we can account for the phosphorescence of the sea in the same way as we have explained the slow combustion which phosphorus undergoes in moist atmospheric air. Agreeably to that view, the light given out by the waters of the ocean must be considered as the effect of a process of oxidation taking place on a most extensive scale, which process is carried on less by the free oxygen of the atmosphere, than by that of the ozone which we suppose to be produced by the catalytic force of the animal matter of the sea.

It is possible that the glow-worm and other animals shining in the dark generate a matter which acts upon atmospheric air in the same way as phosphorus does.

It is one of the facts best known, that carbonic acid is continually produced in the animal body, and that the formation of that compound is intimately connected both with the functions of respiration and the change of

blood. Wherever that carbonic acid may be produced, certain it is that the carbon required for its production comes from the body, and that the oxidation of that element takes place at a temperature at which carbon, being in a free state, does not combine with oxygen. From the large quantities of carbonic acid produced during the respiration of an animal, and the minute quantities of free ozone inhaled, it appears that that carbonic acid cannot be engendered by atmospheric ozone. May we be allowed to suppose that blood being put in contact with atmospheric oxygen acts upon the latter as phosphorus does upon the same oxygen? Is it perhaps to ozone being formed in the way alluded to that the carbonic acid breathed out owes its origin? May we compare, in a chemical point of view, phosphorus placed in atmospheric air to an animal breathing in the same air? Strangely as these questions may sound, we can hardly help putting them, after having discovered in ozone so powerful an oxidizing agent, and found in phosphorus so remarkable a means to produce it.

In spite of the floods of light which recent chemical and physiological researches have thrown upon the function of respiration, we are still very far from understanding thoroughly that phænomenon, and for that very reason every fact which promises to unveil further that mystery is, in my opinion, highly worthy of all the attention both of physiologists and chemical philosophers. And as the subject I have treated of is such as to remind, as it were of itself, of its possible bearings to respiration, I think it will not be left entirely unnoticed.

Considering the great importance of the part which the atmosphere acts in different departments of organic and inorganic nature, it is very desirable that it should become more and more the subject of the most careful and extensive researches, and that chemists in particular should direct their attention to those phænomena which take place in atmospheric air, or are dependent upon the latter; for much as modern science has done in that field of inquiry, it cannot be denied that the greatest mysteries are yet to be unveiled in it. Holding the opinion that the extraordinary action which phosphorus exerts upon atmospheric air discloses to us a fundamental phænomenon, I am inclined to believe that that action, once fully understood, will give us an insight into the cause of a series of phænomena which at this present moment are yet enveloped in utter darkness.

On the Influence of Friction upon Thermo-electricity. *By* Paul Erman *of Berlin.*

[A communication read to the Mathematical and Physical Section, and ordered to be printed entire amongst the Reports.]

Are the forces that govern the interior constitution of bodies *two* in number, and essentially distinct; or do the effects usually called chemical, proceed from the same cause as those to which we give the appellation of mechanical? The future progress of science depends on the solution of this problem, which the recent development of physics has brought almost entirely within the province of electricity. In this province, the two schools, the chemical and the contact of theorists, rival each other in the sagacity and energy they display in the defence of their tenets. Let us indicate however a strategical position, the importance of which the contact party do not appear to have sufficiently seized. Friction is merely a repeated molecular contact, so that the mathematical expression of its effects would perhaps only consist in higher