LECTURE V

OXYGEN PRESENT IN THE AIR-NATURE OF THE ATMOSPHERE-ITS PROPER TIES-OTHER PRODUCTS FROM THE CANDLE-CARBONIC ACID-ITS PROPERTIES

WE have now seen that we can produce hydrogen and oxygen from the water that we obtained from the candle. Hydrogen, you know, comes from the candle, and oxygen, you believe, comes from the air. But then you have a right to ask me, "How is it that the air and the oxygen do not equally well burn the candle?" If you remember what happened when I put a jar of oxygen over a piece of candle, you recollect there was a very different kind of combustion to that which took place in the air. Now, why is this? It is a very important question, and one I shall endeavor to make you understand; it relates most intimately to the nature of the atmosphere, and is most important to us. We have several tests for oxygen besides the mere burning of bodies; you have seen a candle burnt in oxygen or in the air; you have seen phosphorus burnt in the air or in oxygen, and you have seen iron filings burnt in oxygen. But we have other tests besides these, and I am about to refer to one or two of them for the purpose of carrying your conviction and your experience farther. Here we have a vessel of oxygen. I will show its presence to you: if I take a little spark and put it into that oxygen, you know by the experience you gained the last time we met what will happen-if I put that spark into the jar, it will tell you whether we have oxygen here or ;, not. Yes! We have proved it by combustion; and now here is another test for oxygen, which is a very curious and useful one. I have here two jars full of gas, with a plate between them to prevent their mixing; I take the plate away, and the gases are creeping one into the other. "What happens?" say you; "they together produce no such combustion as was seen in the case of the candle." But see how the presence of oxygen is told by its association with this other substance. (16) What a beautifully colored gas I have obtained in this way, showing me the presence of the oxygen! In the same way we can try this experiment by mixing common air with this test-gas. Here is a jar containing air-such air as the candle would burn in- and here is a jar or bottle containing the test-gas. I let them come together over water, and you see the result: the contents of the test. bottle are flowing into the jar of air, and you see I obtain exactly the same kind of action as before, and that shows me that there is oxygen in the air-the very same substance that has been already obtained by us from the water produced by the candle. But then, beyond that, how is it that the candle does not burn in air as well as in oxygen? We will come to that point at once. I have here two jars; they are filled to the same height with gas, and the appearance to the eye is alike in both, and I really do not know at present which of these jars contains oxygen and which contains air, although I know they have previously been filled with these gases. But here is our test-gas, and I am going to work with the two jars, in order to examine whether there is any difference between them in the quality of reddening this gas. I am now going to turn this test-gas into one of the jars, and observe what happens. There is reddening, you see; there is, then, oxygen present. We will now test the other jar; but you see this is not so distinctly red as the first, and, farther, this curious thing happens: if I take these two gases and shake them well together with water, we shall absorb the red gas; and then, if I put in more of this test-gas and shake again, we shall absorb more; and I can go on as long as there be any oxygen present to produce that effect. If I let in air, it will not matter; but the moment I introduce water, the red gas disappears; and I may go on in this way, putting in more and more of the test-gas, until I come to something left behind which will not redden any longer by the use of that particular body that rendered the air and the oxygen red. Why is that? You see in a moment it is because there is, besides oxygen, something else present which is left behind. I will let a little more air into the jar, and if it turns red you will know that some of that reddening gas is still present, and that, consequently, it was not for the want of this producing body that that air was left behind. Now you will begin to understand what I am about to say. You saw that when I burnt phosphorus in a jar, as the smoke produced by the phosphorus and the oxygen of the air condensed, it left a good deal of gas unburnt, just as this red gas left something untouched; there was, in fact, this gas left behind, which the phosphorus can not touch, which the reddening gas can not touch, and this something is not oxygen, and yet is part of the atmosphere. So that is one way of opening out air into the two things of which it is composed-oxygen, which burns our candles, our phosphorus, or any thing else, and this other substance-nitrogen-which will not burn them. This other part of the air is by far the larger proportion, and it is a very curious body when we come to examine it; it is remarkably curious, and yet you say, perhaps, that it is very uninteresting. It is uninteresting in some respects because of this, that it shows no brilliant effects of combustion. If I test it with a taper as I do oxygen and hydrogen, it does not burn like hydrogen, nor does it make the taper burn like oxygen. Try it in any way I will, it does neither the one thing nor the other; it will not take fire; it will not let the taper burn; it puts out the combustion of every thing. There is nothing that will burn in it in common circumstances. It has no smell; it is not sour; it does not dissolve in water; it is neither an acid nor an alkali; it is as indifferent to all our organs as it is possible for a thing to be. And you might say, "It is nothing; it is not worth chemical attention; what does it do in the air?" Ah! then come our beautiful and fine results shown us by an observant philosophy. Suppose, in place of having nitrogen, or nitrogen and oxygen, we had pure oxygen as our atmosphere; what would become of us? You know very well that a piece of iron lit in a jar of oxygen goes on burning to the end. When you see a fire in an iron grate, imagine where the grate would go to if the whole of the atmosphere were oxygen. The grate would burn up more powerfully than the coals; for the iron of the grate itself is even more combustible than the coals which we burn in it. A fire put into the middle of a locomotive would be a fire in a magazine of fuel, if the atmosphere were oxygen. The nitrogen lowers it down and makes it moderate and useful for us, and then, with all that, it takes away with it the fumes that you have seen produced from the candle, disperses them throughout the whole of the atmosphere, and carries them away to places where they are wanted to perform a great and glorious purpose of good to man, for the sustenance of vegetation, and thus does a most wonderful work, although you say, on examining it, "Why, it is a perfectly indifferent thing." This nitrogen in its ordinary state is an inactive element; no action short of the most intense electric force, and then in the most infinitely small degree, can cause the nitrogen to combine directly with the other element of the atmosphere, or with other things round I. about it; it is a perfectly indifferent, and therefore to say, a safe substance. But, before I take you to that result, I must tell you about the atmosphere itself. I have written on this diagram the composition of one hundred parts of atmospheric air:

	Bulk	Weight
Oxygen …….	20	23.3
Nitrogen ……	80	77.7
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	100	100

It is a true analysis of the atmosphere so far as regards the quantity f of oxygen and the quantity of nitrogen present. By our analysis, We find that 5 pints of the atmosphere contain only 1 pint of oxygen, and 4 pints, or 4 parts, of nitrogen by bulk. That is our analysis of the atmosphere. It requires all that quantity of nitrogen to reduce the oxygen down, so as to be able to supply the candle properly with fuel, so as to supply us with an atmosphere which our lungs can, healthily and safely breathe; for it is just as important to make the oxygen right for us to breathe, as it is to make the atmosphere right. for the burning of the fire and the candle. But now for this atmosphere. First of all, let me tell you the weight of these gases. A pint of nitrogen weighs 10 4-10 grains, or a cubic foot weighs 1 1-6 ounces. That is the weight of the nitrogen. The oxygen is heavier: a pint of it weighs 11 9-10 grs., and a cubic foot weighs 1 3-4 oz. A pint of air weighs about 10 7-10 grs., and a cubic foot 1 1-5 oz. You have asked me several times, and I am very glad you have, "How do you weigh gases?" I will show you: it is very simple, and easily done. Here is a balance, and here a copper bottle, made as light as we can consistent with due strength, turned very nicely in the lathe, and made perfectly air-tight, with a stop-cock, which we can Iii open and shut, which at present is open, and, therefore, allows the bottle to be full of air. I have here a nicely-adjusted balance in which I think the bottle, in its present condition, will be balanced by the weight on the other side. And here is a pump by which we can force the air into this bottle, and with it we will force in a certain number of volumes of air as measured by the pump. [Twenty measures were pumped in.] We will shut that in and put it in the balance. See how it sinks; it is much heavier than it was. By what? By the air that we have forced into it by the pump. There is not a greater bulk of air, but there is the same bulk of heavier air, because we have forced in air upon it. And that you may have a fair notion in your mind as to how much this air measures, here is a jar full of water. We will open that copper vessel into, this jar, and let the air return to its former state. FIG. 79. All I have to do now is to screw them tightly together, and to turn the taps, when there, you see, is the bulk of the twenty pumps of air which I forced into the bottle; and to make sure that we have been quite correct in what we have been doing, we will take the bottle again to the balance, and, if it is now counterpoised by the original weight, we shall be quite sure we have made our experiment correctly.

It is balanced; so, you see, we can find out the weight of the extra volumes of air forced in in that way, and by that means we are able to ascertain that a cubic foot of air weighs 1 1-5 oz. But that small experiment will by no means convey to your mind the whole literal truth of this matter. It is wonderful how it accumulates when you come to larger volumes. This bulk of air [a cubic foot] weighs 1 1-5 oz. What do you think of the contents of that box above there which I have had made for the purpose? The air which is within that box weighs one pound-a full pound; and I have calculated the weight of the air in this room: you would hardly imagine it, but it is above a ton. So rapidly do the weights rise up, and so important is the presence of the atmosphere, and of the oxygen and the nitrogen in it, and the use it performs in conveying things to and from place to place, and carrying bad vapors to places where they will do good instead of harm. Having given you that little illustration with respect to the weight of the air, let me show you certain consequences of it. You have a right to them, because you would not understand so much without it. Do you remember this kind of experiment? Have you ever seen it? Suppose I take a pump somewhat similar to the one I had a little while ago to force air into the bottle, and suppose I place it in such a manner that by certain arrangements I can apply my hand to it. My hand moves about in the air so easily that it seems to feel nothing, and I can hardly get velocity enough by any motion of my own in the atmosphere to make sure that there is much resistance to it. But when I put my hand here [on the air-pump receiver, which was afterward exhausted] you see what happens. FIG. 80. Why is my hand fastened to this place, and why am I able to pull this pump about? And see! how is it that I can hardly get my hand away? Why is this? It is the weight of the air-the weight of the air that is above. I have another experiment here, which I think will explain to you more about it. When the air is pumped from underneath the bladder which is stretched over this glass, you will see the effect in another shape: the top is quite flat at present, but I will make a very little motion with the pump, and now look at it; see how it has gone down, see how it is bent in; you will see the bladder go in more and more, until, at last, I expect it will be driven in and broken by the force of the atmosphere pressing upon it. [The bladder at last broke with a loud report.] Now that was done entirely by the weight of the air pressing on it, and you can easily understand how that is. The particles that are piled up in the atmosphere stand upon each other, as these five cubes do; you can easily conceive that four of these five cubes are resting upon the bottom one, and if I take that away the others will all sink down. So it is with the atmosphere; the air that is above is sustained by the air that is beneath, and when the air is pumped away from beneath them, the change occurs which you saw when I placed my hand on the air-pump, and which you saw in the case of the bladder, and which you shall see better here. FIG. 81. I have tied over this jar a piece of sheet India-rubber, and I am now about to take away the air from the inside of the jar; and if you will watch the India-rubber-which acts as a partition between the air below and the air above-you will see, when I pump, how the pressure shows itself. See where it is going to: I can actually put my hand into the jar; and yet this result is only caused by the great and powerful action of the air above. How beautifully it shows this curious circumstance! Here is something that you can have a pull at when I have finished to--day. It is a little M apparatus of two hollow brass hemispheres, closely fitted together, and having connected with it a pipe and a cock, through which we can exhaust the air from the inside; and although the two halves are so easily taken apart, while the air is left within, yet you will see, when we exhaust it by-and-by, no power of any two of you will be able to pull them apart. FIG. 82. Every square inch of surface that is contained in the area of that vessel sustains fifteen pounds by weight, or nearly so, when the air is taken out, and you may try your strength presently in seeing whether you can overcome that pressure of the atmosphere. Here is another very pretty thing-the boys' sucker, only refined by the philosopher. We young ones have a perfect right to take toys, and make them into philosophy, inasmuch as nowadays we are turning philosophy into toys. Here is a sucker, only it is made of India- rubber. If I clap it upon the table, you see at once it holds. Why does it hold? I can slip it about, and yet if I try to pull it up, it seems as if it would pull the table with it. I can easily make it slip about from place to place, but only when I bring it to the edge of the table can I get it off. It is only kept down by the pressure of the atmosphere above; we have a couple of them, and if you take these two and press them together, you will see how firmly they stick. And, indeed, we may use them as they are proposed to be used, to stick against windows, or against walls, where they will adhere for an evening, and serve to hang any thing on that you want. I think, however, that you boys ought to be shown experiments that you can make at home; and so here is a very pretty experiment in illustration of the pressure of the atmosphere. Here is a tumbler of water. Suppose I were to ask you to turn that tumbler upside down so that the water should not fallout, and yet not be kept in by your hand, but merely by using the pressure of the atmosphere; could you do that? Take a wine-glass, either quite full or half full of water, and put a flat card on the top; turn it upside down, and then see what becomes of the card and of the water. The air can not get in because the water, by its capillary attraction round the edge, keeps it out. I think this will give you a correct notion of what you may call the materiality of the air; and when I tell you that that box holds a pound of it, and this room more than a ton, you will begin to think that air is something very serious. I will make another experiment to convince you of this positive resistance. There is that beautiful experiment of the popgun, made so well and so easily, you know, out of a quill, or a tube, or any thing of that kind,-where we take a slice of potato, for instance, or an apple, and take the tube and cut out a pellet, as I have now done, and push it to one end. I have made that end tight; and now I take another piece and put it in: it will confine the air that is within the tube perfectly and completely for our purpose; and I shall now find it absolutely impossible by any force of mine to drive that little pellet close up to the other. It can not be done; I may press the air to a certain extent, but if I go on pressing, long before it comes to the second, the confined air will drive the front one out with a force something like that of gunpowder; for gunpowder is in part dependent upon the same action that you see here exemplified. I saw the other day an experiment which pleased me much, as I thought it would serve our purpose here. (I ought to have held my tongue for four or five minutes before beginning this experiment, because it depends upon my lungs for success.) By the proper application of air, I expect to be able to drive this egg out of one cup into the other by the force of my breath; but if I fail it is in a good cause, and I do not promise success, because I have been talking more than I ought to do to make the experiment succeed. [The lecturer here tried the experiment, and succeeded in blowing the egg from one egg cup to the other.] You see that the air which I blow goes downward between the egg and the cup, and makes a blast under the egg, and is thus able to lift a heavy thing; for a full egg is a very heavy thing for air to lift. If you want to make the experiment, you had better boil the egg quite hard first, and then you may very safely try to blow it from one cup to the other, with a little care. I have now kept you long enough upon this property of the weight of the air, but there is another thing I should like to mention. You saw the way in which, in this popgun, I was able to drive the second piece of potato half or two-thirds of an inch before the first piece started, by virtue of the elasticity of the air, just as I pressed into the copper bottle the particles of air by means of the pump. Now this depends upon a wonderful property in the air, namely, its elasticity, and I should like to give you a good illustration of this. If I take any thing that confines the air properly, as this membrane, which also is able to contract and expand so as to give us a measure of the elasticity of the air, and confine in this bladder a certain portion of air; and then, if we take the atmosphere off from the outside of it, just as in these cases we put the pressure on-if we take the pressure off, you will see how it will then go on expanding and expanding, larger and larger, until it will fill the whole of this bell jar, showing you that wonderful property of the air, its elasticity, its compressibility, and expansibility, to an exceedingly large extent, and which is very essential for the purposes and services it performs in the economy of creation. We will now turn to another very important part of our subject, remembering that we have examined .the candle in its burning, and have found that it gives rise to various products. We have the products, you know, of soot, of water, and of something else, which you have not yet examined. We have collected the water, but have allowed the other things to go into the air. Let us now examine some of these other products. Here is an experiment which I think will help you in part in this way. We will put our candle there, and place over it a chimney, thus. FIG.83. I think my candle will go on burning, because the air passage is open at the bottom and the top. In the first place, you see the moisture appearing-that you know about. It is water produced from the candle by the action of the air upon its hydrogen. But, besides that, something is going out at the top: it is not moisture-it is not water-it is not condensible; and yet, after all, it has very singular properties. You will find that the air coming out of the top of our chimney is nearly sufficient to blow the light out I am holding to it; and if I put the light fairly opposed to the current, it will blow it quite out. You will say, that is as it should be, and I am supposing that you think it ought to do so, because the nitrogen does not support combustion, and ought to put the candle out, since the candle will not burn in nitrogen. But is there nothing else there than nitrogen? I must now anticipate-that is to say, I must use my own knowledge to supply you with the means that we adopt for the purpose of ascertaining these things, and examining such gases as these. I will take an empty bottle-here is one-and if I hold it over this chimney, I shall get the combustion of the candle below sending its results into the bottle above; and we shall soon find that this bottle contains, not merely an air that is bad as regards the combustion of a taper put into it, but having other properties. Let me take a little quick-lime and pour some common water on to it-the commonest water will do. I will stir it a moment, then pour it upon a piece of filtering paper in a funnel, and we shall very quickly have a clear water proceeding to the bottle below, as I have here. I have plenty of this water in another bottle, but nevertheless I should like to use the lime-water that was prepared before you, so that you may see what its uses are. If I take some of this beautiful clear lime-water, and pour it into this jar which has collected the air from the candle, you will see a change coming about. Do you see that the water has become quite milky? Observe, that will not happen with air merely. Here is a bottle filled with air; and if I put a little lime-water into it, neither the oxygen nor the nitrogen, nor any thing else that is in that quantity of air, will make any change in the lime-water. It remains perfectly clear, and no shaking of that quantity of lime-water with that quantity of air in its common state will cause any change; but if I take this bottle with the lime-water and hold it so as to get the general products of the candle in contact with it, in a very short time we shall have it milky. There is the chalk, consisting of the lime which we used in making the lime-water, combined with something that came from the candle - that other product which we are in search of, and which I want to tell you about today. This is a substance made visible to us by its action, which is not the action of the lime-water either upon the oxygen or upon the nitrogen, nor upon the water itself, but it is something new to us from the candle. And then we find this white powder, produced by the lime-water and the vapor from the candle, appears to us very much like whitening or chalk, and when examined it does prove to be exactly the same substance as whitening or chalk. So we are led, or have been led, to observe upon the various circumstances of this experiment, and to trace this production of chalk to its various causes, to give us the true knowledge of the nature of this combustion of the candle-to find that this substance issuing from the candle is exactly the same as that substance which would issue from a retort if I were to put some chalk into it with a little moisture and make it red-hot; you would then find that exactly the same substance would issue from it as from the candle. But we have a better means of getting this substance, and in greater quantity, so as to ascertain what its general characters are. We find this substance in very great abundance in a multitude of cases where you would least expect it. All limestones contain a great deal of this gas which issues from the candle, and which we call carbonic acid. All chalks, all shells, all corals, contain a great quantity of this curious air. We find it fixed in these stones, for which reason Dr. Black called it "fixed air"-finding it in these fixed things .like marble and chalk-he called it fixed air because it lost its quality of air, and assumed the condition of a solid body. We can easily get this air from marble. Here is a jar containing a little muriatic acid, and here is a taper which, if I put it into that jar, will show only the presence of common air. There is, you see, pure air [down to the bottom; the jar is full of it. Here is a substance-marble (17), a very beautiful and superior marble-and if I put these pieces of marble into the jar, a great boiling apparently goes on. That, however, is not steam; It is a gas that is rising up; and If I now f search the jar by a candle, I shall have exactly the same effect produced upon the taper as I had from the air which issued from the end of the chimney over the burning candle. It is exactly the same action, and caused by the very same substance that issued from the candle; and in this way we can get carbonic acid in great abundance -we have already nearly filled the jar. We also find that this gas is not merely contained in marble. Here is a vessel in which I have I put some common whitening-chalk which has been washed in water and deprived of its coarser particles, and so supplied to the I plasterer as whitening-here is a large jar containing this whitening and water; and I have here some strong sulphuric acid, which is the I acid you might have to use if you were to make these experiments (only, in using this acid with limestone, the body that is produced is an insoluble substance, whereas the muriatic acid produces a soluble substance that does not so much thicken the water). And you will seek out a reason why I take ,this kind of apparatus for the purpose of showing this experiment. I do it because you may repeat in a small way what I am about to do in a large one. You will have here just the same kind of action; and I am evolving in this large jar carbonic acid exactly the same in its nature and properties as the gas which we obtained from the combustion of the candle in the atmosphere. And, no matter how different the two methods by which we prepare this carbonic acid, you will see, when we get to the end of our subject, that it is all exactly the same, whether prepared in the one way or in the other. We will now proceed to the next experiment with regard to this gas. What is its nature? Here is one of the vessels full, and we will try it as we have done so many other gases-by combustion. You see it is not combustible, nor does it support combustion. Neither, as we know, does it dissolve much in water, because we collect it over water very easily. Then you know that it has an effect, and becomes white in contact with lime-water; and when it does become white in that way, it becomes one of the constituents to make carbonate of lime or limestone. The next thing I must show you is that it really does dissolve a little in water, and therefore that it is unlike oxygen and hydrogen in that respect. I have here an apparatus by which we can produce this solution. In the lower part of this apparatus is marble and acid, and in the upper part cold water. The valves are so arranged that the gas can get from one to the other. I will set it in action now, and you can see the gas bubbling up through the water, as it has been doing all night long, and by this time we shall find that we have this substance dissolved in the water. If I take a glass and draw off some of the water, I find that it tastes a little acid to the mouth; it is impregnated with carbonic acid; and if I now apply a little lime- water to it, that will give us a test of its presence. This water will make the lime-water turbid and white, which is proof of the presence of carbonic acid. Then it is a very weighty gas; it is heavier than the atmosphere. I have put their respective weights at the lower part of this table, along with, for comparison, the weights of the other gases we have been examining:

	Pint	Cubic Foot
Hydrogen	3/4 grs.	1/12 oz.
Oxygen	11 9/10	1 1/3
Nitrogen	10 4/10	1 1/6
Air	10 7/10	1 1/5
Carbonic Acid	16 1/3	1 9/10

A pint of it weighs 16 1-3 grains, and a cubic foot weighs 1 9-10 ounce, almost two ounces. You can see by many experiments that this is a heavy gas. Suppose I take a glass containing nothing else but air, and from this vessel containing the carbonic acid I attempt to pour a little of this gas into that glass- I wonder whether any has gone in or not. I can not tell by the appearance, but I can in this way [introducing the taper]. Yes, there it is, you see; and if I were to examine it by lime-water, I should find it by that test also. I will take this little bucket, and put it down into the well of carbonic acid-indeed, we too often have real wells of carbonic acid- and now, if there is any carbonic acid, I must have got to it by this time, and it will be in this bucket, which we will examine with a taper. There it is, you see; it is full of carbonic acid. FIG. 84. There is another experiment by which I will show you its weight. I have here a jar suspended at one end of a balance-it is now equipoised; but when I pour this carbonic acid into the jar on the one side which now contains air, you will see it sink down at once because of the carbonic acid that I pour into it. And now, if I examine this jar with the lighted taper, I shall find that the carbonic acid has fallen into it, and it no longer has any power of supporting the combustion. If I blow a soap bubble, which of course will be filled with air, and let it fall into this jar of carbonic acid, it will float. But I shall first of all take one of these little balloons filled with air. I am not quite sure where the carbonic acid is; we will just try the depth, and see whereabouts is its level. FIG. 85. There, you see, we have this bladder floating on the carbonic acid; and if I evolve some more of the carbonic acid, the bladder will be lifted up higher. There it goes; the jar is nearly full, and now I will see whether I can blow a soap bubble on that and float it in the same way. [The lecturer here blew a soap bubble and allowed it to fall into the jar of carbonic acid, when it floated in it midway.] It is floating, as the balloon floated, by virtue of the greater weight of the carbonic acid than of the air. And now, having so far given you the history of the carbonic acid, as to its sources in the candle, as to its physical properties and weight, when we next meet I shall show you of what I it is composed, and where it gets its elements from.

16 The gas which is thus employed as a test for the presence of oxygen is the binoxide of nitrogen, or nitrous oxide. It is a colorless gas, which, when brought in contact with oxygen, unites with it, forming hyponitric acid, the red gas referred to.

17 Marble is a compound of carbonic acid and lime. The muriatic acid, being the stronger of the two, takes the place of the carbonic acid, which escapes as a gas, the residue forming muriate of lime or chloride of calcium.