THE CHEMICAL HISTORY OF A CANDLE.

By Professor Faraday.

A Course of Six Lectures (adapted to a Juvenile Audience) Delivered before the Royal Institution of Great Britain.

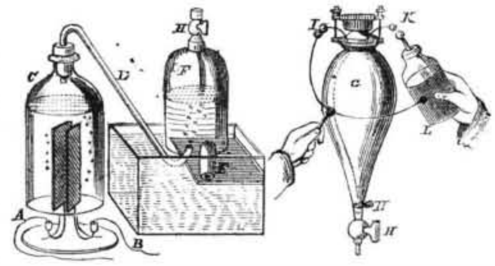
LECTURE IV.

Products: Water from the Combustion—Nature of Water—A Compound—Hydrogen.

I see you are not tired of the candle yet, or I am sure you would not be interested in the subject in the way you are. When our candle was burning we found it produced water exactly like the water we have around us; and by further examination of this water we found in it that curious body, hydrogen—that light substance of which there is some in this jar. We afterward saw the burning powers of that hydrogen, and that it produced water. And I think I introduced to your notice an apparatus which I very briefly said was an arrangement of chemical force, or power, or energy, so adjusted as to convey its power to us in these wires; and I said I should use that force to pull the water to pieces, to see what else there was in the water besides hydrogen; because, you remember, when we passed the water through the iron tube, we by no means got the weight of water back which we put in in the form of steam, though we had a very large quantity of gas evolved. We have now to see what is the other substance present. That you may understand the character and use of this instrument, let us make an experiment or two. Let us put together, first of all, some substances, knowing what they are, and then see what that instrument does to them. There is some copper (observe the various changes which it can undergo), and here is some nitric acid, and you will find that this, being a strong chemical agent, will act very much when I add it to the copper. It is now sending forth a beautiful red vapor; but as we do not want that vapor, Mr. Anderson will hold it near the chimney for a short time, that we may have the use and beauty of the experiment without the annoyance. The copper which I have put into the flask will dissolve; it will change the acid and the water into a blue fluid containing copper and other things, and I purpose then showing you how this voltaic battery deals with it; and in the meantime we will arrange another kind of experiment for you to see what power it has. This is a substance which is to us like water—that is to say, it contains bodies which we do not know of as yet, as water contains a body which we do not know as yet. Now this solution of a salt I will put upon paper and spread about, and apply the power of the battery to it, and observe what will happen. Three or four important things will happen which we shall take advantage of. I place this wetted paper upon a sheet of tin foil, which is convenient for keeping all clean, and also for the advantageous application of the power; and this solution, you see, is not at all affected by being put upon paper or tin foil, nor by anything else I have brought in contact with it, and which, therefore, is free to us to use as regards that instrument. But first let us see that our instrment is in order. Here are our wires. Let us see whether it is in the state in which it was last time. We can soon tell. As yet, when I bring them together, we have no power, because the conveyers—what we call the electrodes—the passages or ways for the electricity—are stopped; but now Mr. Anderson by that [referring to a sudden flash at the ends of the wires] has given me a telegram to say that it is ready. Before I begin our experiment I will get Mr. Anderson to break contact again at the battery behind me, and we will put a platinum wire across to connect the poles, and then if I find I can ignite a pretty good length of this wire we shall be safe in our experiment. Now you will see the power. [The connection was established and the intermediate wire became red hot.] There is the power running beautifully through the wire, which I have made thin on purpose to show you that we have those powerful forces; and now, having that power, we will proceed with it to the examination of water.

I have here two pieces of platinum, and if I lay them down upon this piece of paper [the moistened paper on the tin foil] you will see no action; and if I take them up there is no change that you can see, but the arrangement remains just as it was before. But now see what happens; if I take these two poles and put either one or the other of them down separately on the platinum plates, they do nothing for me, both are perfectly without action; but if I let them both be in contact at the same moment, see what happens [a brown spot appeared under each pole of the battery]. Look here at the effect that takes place, and see how I have pulled something apart from the white—something brown; and I have no doubt, if I were to arrange this, and were to put one of the poles to the tinfoil on the other side of the paper, why, I get such a beautiful action upon the paper, that I am going to see whether I cannot write with it—a telegram, if you please [the lecturer here traced the word "juvenile" on the paper with one of the terminal wires]. See there how beautifully we can get our results.

You see we have here drawn something, which we have not known about before, out of this solution. Let us now take that flask from Mr. Anderson's hands, and see what we can draw out of that. This, you know, is a liquid which we have just made up from copper and nitric acid, whilst our other experiments were in hand, and though I am making this experiment very hastily, and may bungle a little, yet I prefer to let



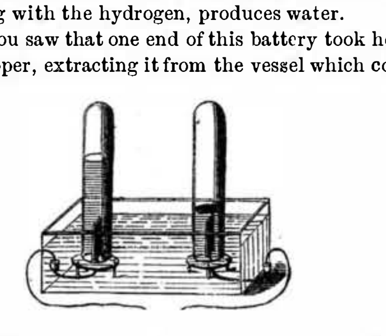
you see what I do rather than prepare it beforehand.

Now see what happens. These two platinum plates are the two ends (or I will make them so immediately) of this apparatus; and I am about to put them in contact with that solution, just as we did a moment ago on the paper. It does not matter to us whether the solution be on the paper or whether it be in the jar, so long as we bring the ends of the apparatus to it. If I put the two platinums in by themselves, they come out as clean and as white as they go in [inserting them into the fluid without connecting them with the battery]; but when we take the power and lay that on [the platinums were connected with the battery and again dipped into the solution], this, you see [exhibiting one of the platinums] is at once turned into copper, as it were; it has become like a plate of copper; and that [exhibiting the other piece of platinum] has come out quite clean. If I take this coppered piece and change sides, the copper will leave the right-hand side and come over to the left-hand side; what was before the coppered side comes out clean, and the plate which was clean comes out coated with copper; and you thus see that what copper we put into this solution we can also take out of it by means of this instrument.

Putting that solution aside, let us now see what effect this instrument will have upon water. Here are two little platinum plates which I intend to make the ends of the battery, and this, C, is a little vessel so shaped as to enable me to take it to pieces, and show you its construction. In these two cups, A and B, I pour mercury, which touches the ends of the wires connected with the platinum plates. In the vessel, C, I pour some water containing a little acid (but which is put only for the purpose of facilitating the action—it undergoes no change in the process), and connected with the top of the vessel is a bent glass tube, D, which may remind you of the pipe which was connected with the gun barrel in our furnace experiment, and which now passes under the jar, F. I have now adjusted this apparatus, and we will proceed to affect the water in some way or other. In the other case, I sent the water through a tube which was made red hot; I am now going to pass the electricity through the inside of this vessel. Perhaps I may boil the water; if I do boil the water I shall get steam; and you know that steam condenses when it gets cold, and you will therefore see, by that, whether I do boil the water or not. Perhaps, however, I shall not boil the water, but produce some other effect. You shall have the experiment and see. There is one wire which I will put to this side, A, and here is the other wire which I will put to the other side, B, and you will soon see whether any disturbance takes place. Here it is seeming to boil up famously; but does it boil? Let us see whether that which goes out is steam or not. I think you will soon see the jar, F, will be filled with vapor, if that which rises from the water is steam. But can it be steam? Why, certainly not; because there it remains, you see, unchanged. There it is standing over the water, and it therefore cannot be steam, but must be a permanent gas of some sort. What is it? Is it hydrogen; is it steam; is it anything else? Well, we will examine it. If it is hydrogen it will burn. [The lecturer then ignited the gas collected, which burnt with an explosion.] It is certainly something combustible, but not combustible in the way that hydrogen is. Hydrogen would not have given you that noise, but the color of that light when the thing did burn was like that of hydrogen; it will, however, burn without contact with the air. That is why I have chosen this other form of apparatus for the purpose of pointing out to you what are the particular circumstances of this experiment. In place of an open vessel, I have taken one that is closed; (our battery is so beautifully strong, that we are even boiling the mercury, and getting all things right—not wrong, but vigorously right); and I am going to show you that that gas, whatever it may be, can burn without air; and in that respect differs from a candle, which cannot burn without the air. And our manner of doing that is as follows:—I have here a glass vessel, G, which is fitted with two platinum wires, I K, through which I can apply electricity; and we can put the vessel on the air pump and exhaust the air, and when we have taken the air out we can bring it here and fasten it on to this jar, F, and let that gas into the vessel which was formed by the action of the voltaic battery upon the water, and which we have produced by changing the water into it—for I may go so far as this, and say we have merely, by that experiment, changed the water into that gas. We have not only altered its condition, but we have changed it really and truly into that gaseous substance; and all water is there which was decomposed by the experiment. As I screw this vessel, G H, on here, H', and make the tubes well connected, and when I open the stop cocks, H H H', if you watch the level of the water in F, you will see that that gas will rise. Now, I will close the stop cocks, as I have drawn up as much as that vessel can hold, and being safely conveyed into that chamber, I will pass into it an electric spark from this Leyden jar, L, and the vessel, which is now quite clear and bright, will become dim. There will be no sound, for the vessel is strong enough to confine the explosion. [A spark was then passed through the jar, when the explosive mixture was ignited.] Did you see that brillant light? If I again screw the vessel on to the jar, and open these stop cocks, you will see that the gas will rise a second time. [The stop cocks were then opened.] Those gases [referring to the gases first collected in the jar, and which had just been ignited by the electric spark] have disappeared, as you see; their place is vacant, and fresh gas has gone in. Water has been formed of them; and if we repeat our operation [repeating the last experiment], I shall have another vacancy, as you will see by that water rising. I always have an empty vessel after the explosion, because the vapor or gas into which the water has been resolved by the battery, explodes under the influence of the spark, and changes into water; and by and by you will see in this upper vessel some drops of water trickling down the sides and collecting at the bottom.

We are here dealing with water entirely, without reference to the atmosphere. The water of the candle had the atmosphere helping to produce it; but in this way it can be produced independently of the air. Water, therefore, ought to contain that other substance which the candle takes from the air, and which, combining with the hydrogen, produces water.

Now, you saw that one end of this battery took hold of the copper, extracting it from the vessel which con-



tained the blue solution. It was effected by this wire; and surely we may say if the battery has such power with a metallic solution which we made and unmade, may we not think that it is possible that it can split asunder the component parts of the water, and put them into this place and that place? Suppose I take the poles—the metallic ends of this battery—and see what will happen with the water in this apparatus, where we have separated the two ends far apart. I place one here (at A), and the other there (at B), and I have little shelves with holes which I can put upon each pole, and so arrange them that whatever escapes from the two ends of the battery will appear as separate gases; for you saw that the water did not become vaporous but gaseous. The wires are now in perfect and proper connection with the vessel containing the water, and you see the bubbles rising; let us collect these bubbles and see what they are. Here is a glass cylinder, O, I fill it with water and put it over one end, A, of the pile, and I will take another, H, and put it over the other end, B, of the pile. And so now we have a double apparatus, with both places delivering gas. Both these jars will fill with gas. There they go, that to the right (H) filling very rapidly; the one to the left (O) filling not so rapidly; and though I have allowed some bubbles to escape, yet still the action is going on pretty regularly, and were it not that one is rather smaller than the other, you would see that I should have twice as much in this (H) as I have in that (O). Both these gases are colorless; they stand over the water without condensing; they are alike in all things—I mean in all *apparent* things; and we have here an opportunity of examining these bodies and seeing what they are. Their bulk is large, and we can easily apply experiments to them. I will take this jar (H) first, and will ask you to be prepared to recognize hydrogen.

Think of all its qualities—the light gas which stood well in inverted vessels, burning with a pale flame at the mouth of the jar, and see whether this gas does not satisfy all these conditions. If it be hydrogen, it will remain here while I hold this jar inverted. [A light was then applied and the hydrogen burned.] What is there now in the other jar? You know that the two together made an explosive mixture. But what can this be which we find as the other constituent in water, and which must, therefore, be that substance which made the hydrogen burn? We know that the water we put into the vessel consisted of the two things together. We find one of these is hydrogen; what must that other be which was in the water before the experiment, and which we have now by itself? I am about to put this lighted splinter of wood into the gas. The gas itself will not burn, but it will make the splinter of wood burn. [The lecturer ignited the end of the wood and introduced it into the jar of gas.] See how it invigorates the combustion of the wood, and how it makes it burn far better than the air would make it burn, and now you see by itself that every other substance which is contained in the water, and which, when the water was formed by the burning of the candle, must have been taken from the atmosphere. What shall we call it, A, B, or C? Let us call it O—call it "Oxygen;" it is a very good distinct-sounding name. This, then, is the oxygen which was present in the water, forming so large a part of it.

Great Importance of a Smooth and Solid Track for Railroads.

The following weighty remarks by Mr. Holley, in his recent work on "Railway Practice," are certainly worthy of the attention of every person who is interested in the construction of railroads :—

In a former work, Mr. Zerah Colburn and the author laid before the public, in considerable detail, the comparative working expenses of European and American railways. It was shown that the cost of maintaining the permanent way, and of maintaining and working the trains, was, in round numbers, one-half as much on English as on American lines; and that the economy of the former was due chiefly to smoother and more permanent way-bed and superstructure.

The excessive first cost of the British railway system was shown to consist chiefly in land and parliamentary expenses; in tunnels, bridges, viaducts and stations, far exceeding in magnitude and cost the actual requirements of at least American lines, and in other items which do not contribute to the economical movement of trains.

The simple "track" of a first-class English line was found to have cost about $1,500 per mile more than that of an ordinary American line, at the respective prices of material and labor in the two counrties.

However greatly individual American lines may have been improved within the last two or three years, it is evident that the same differences in construction and working still characterize the systems of the two countries. But the European system is practically acknowledged to be quite imperfect by the many attempts made to improve it, by the extensive experiments now in process with each promising new invention and adaptation, and by the increasing diversity in the practice of different lines.

Extension of Hoe's Patent in England.

The *London American* announces that the Judicial Committee of the Privy Council extended Hoe's English patent for printing machines. Mr. Richard M. Hoe, of New York, was the inventor; but the nominal patentee, and one of the petitioners, was Mr. William Newton. Mr. Grove, the counsel for the petitioners, stated to the Committee the advantages possessed by this printing press over the celebrated Applegarth machine. Both are used by the *Times*, the latter, however, only as "aids." He described the nature of the invention, and stated that one of Mr. Hoe's ten-feeder machines could print from 20,000 to 25,000 newspapers in an hour. The efforts made by the patentee had involved a vast amount of industry and skill. Mr. Hoe came over to this country in 1847, but it was nine years from the date of his patent before he could get anything done, and English sales had been only fourteen machines. By the inventor's accounts, which were presented, it seems that the profits from the patent, were £7,000, but of this £4,000 went to Mr. Hoe's partners, and he had only received £3,000, which was a most inadequate remuneration for an invention of such importance, especially to the cheap press, which was obliged to use thin paper, for which Applegarth's machine is not applicable.

Several eminent engineers bore testimony to the value of the invention, and Mr. Welsby, on behalf of the Crown, made no opposition.

Lord Cranworth delivered the judgment of their lordships, who, he said, were all satisfied that this was a most useful invention—one of great merit and simplicity, as far as simplicity could apply to such an invention. They thought that the inventor had not derived that reasonable profit which he had a right to expect. He had been for several years without profit, and in his accounts he had placed many charges on the debtor side of the account with which he might have credited himself. Under all the circumstances, their lordships would advise Her Majesty to extend the patent.

The Streets of London.

Some of the facts stated by Mr. Gough, in his lecture on the "Streets of London," are very curious. He says the population is increasing at the rate of 1,000 per week; from this it follows that, in the average, in every hour of the day and night there are six persons in London more than there were the hour before. The city is 60 miles in circumference, and has 5,000 miles of paved streets. Land in the vicinity of Cornhill and the Exchange has been sold for $5,000,000 per acre. The fog of London had never been adequately described. It was an odd sensation, when he was speaking in Exeter Hall, produced in the course of a few minutes, not to be able to see one in the crowded galleries—to be speaking to people, and see nobody there. If you go out in the streets, it seems as if you were wading in an illuminated sea of pea soup. These fogs never rise higher than 200 feet above the city; they come in December, and are never seen after February. They are supposed to be caused by the smoke of bituminous coal issuing from innumerable chimneys. As an illustration of the benevolence of London, the lecturer instanced the amount raised for the soldiers in the Crimea—$6,500,000 in less than six months by subscription. In the prisons the prisoners said they could not give money, but they would give their provisions, and they starved themselves twenty-four hours so that the amount of a day's provisions could go into the sum. The lecturer described the ragged schools, of which there are 170, with 25,000 pupils; also the various shifts made to get a living. Nothing is wasted in London—the hoofs and nostrils of dead horses serve to make a fine gelatine, and the blood is used to give a particularly nice flavor to catsup. Mr. Gough closed with a humorous account of the celebration of Guy Fawkes's day, the 5th of November.

Essence of Verbena Leaf.—A sweet and refreshing perfume for the handkerchief. Take rectified spirits of wine, half a pint; otto of verbena, half a drachm; otto of bergamot, one drachm; and tincture of tolu, a quarter of an ounce. Mix them together, and it is ready for use. This sweet scent does not stain the handkerchief, and is very economical. No one must suppose for a moment that this essence will be good unless it is made of pure ingredients.

Turkey and American Civilization.

A series of deeply interesting lectures have lately been given in New York and Brooklyn, by Rev. Cyrus Hamlin, D D., who has been a resident of Constantinople for the past twenty years. There is no Christian living, we believe, who understands the Moslem character and the affairs of Turkey better than Dr. Hamlin, or who has done so much to introduce the agents of modern civilization—science and the useful arts—among the Turks of Constantinople. He has a thorough appreciation of the value of improved machinery, as we understand he was a practical mechanic in his younger days, and worked at his trade in Bangor, Maine. Having formed a resolution to preach the Gospel as a missionary, he studied theology and acquired a scientific education, and when he went to Constantinople, he took out working models of several improved American machines, the uses of which he explained to the Sultan, to whom he was introduced for the purpose, and who has ever been friendly toward him.

At one period a number of converts, principally mechanics, from the Armenian Church, were subjected to a silent, but very crushing persecution from their own people, by secret measures being carried out to prevent their obtaining employment, but the Yankee genius and enterprise of Dr. Hamlin met and overcame the evil. With the material assistance of some good friends, he erected a grist mill and bakery, and made flour and bread of a superior quality. By these means he gave the persecuted Armenian converts honest and profitable employment, and it was through his agency that the allied army in the vicinity of Constantinople was supplied with fresh bread during the Crimean war. The British soldiers, who had been formerly fed on musty biscuits that could almost walk alone, received their first supplies of Dr. Hamlin's bread with almost frantic rejoicings. The loaves were stuck upon the ends of their bayonets, raised aloft above their heads, cheers were given for the American missionary baker, and away went their old musky biscuits pell mell into the river.

Dr. Hamlin intends to return again to Turkey, and will take a number of American machines with him. He purposes to complete an American College in Constantinople on a commanding elevation, and thus with the holy influence of Christian education, he will carry our useful arts to the banks of the Bosphorus.

Substitute for Rifled Cannon.

A method has been invented of dispensing with rifling cannons, and, at the same time, securing long range and unerring accuracy of flight. The particulars given of this invention are as follows:—First, the breech is bored, say one-eighth of an inch larger than the bore of the gun, the projectile, which is elongated, being constructed to fit the breech; second, the projectile is coated with a soft metal, with a hole through the center from end to end; third, immediately when the projectile enters the gun, it meets with a shoulder which takes off a shaving, thus molding it to the exact size of the gun, thereby precluding all windage; fourth, on the projectile leaving the gun, the air forces out the "bevel" plug at the back; the air then, having a free passage through the projectile, prevents the possibility of its diverging either left or right, or turning over; on the contrary, it causes it to travel with astonishing and unerring precision. The sudden expansion of air at the back considerably assists its onward course.

We have seen the above in several of our cotemporaries; it is very liable to mislead those who are not acquainted with the subject. It is not the prevention of windage which gives the rifle ball such accuracy in comparison with smooth-bored firearms, but its rotary motion, by which it is made to rotate around an axis during its entire flight. No provision is made in the above construction of cannon and ball, as described, to give the latter a spinning motion; consequently, the invention cannot be a substitute for rifled cannon.

New Coating for Telegraph Wires.—Mr. J. Macintosh, of London, in the patent taken out recently by him, says: "When telegraph wires are insulated with gutta-percha, minute pores exist in the covering, and when insulated with india-rubber, it absorbs from 18 to 25 per cent of water." To remedy these defects Mr. Macintosh mixes gutta-percha and india-rubber with parafine or stearic acid. The proportions are about 75 parts of gutta-percha or india-rubber, to 25 parts by weight of stearic acid. These substances, in such proportions, are mixed together by grinding it in the common manner and applying it hot to cover the wires.