stant mixture, preventing stratification or contamination through the exhalations of the subject. The cylinder being of glass and perfectly transparent, enables the operator to observe every change in the condition of the animal.

The author found in recent experiments that he made in his laboratory that, notwithstanding the deadly claims made for carbonic acid gas, a rabbit existed with very little evidence of dissolution in an atmosphere of 25 per cent. of carbonic acid gas and 75 per cent. of air. This one fact alone is of great importance to the miner in case of an explosion followed by after-damp, for though 50 per cent. of carbonic acid gas will overcome him very quickly, he could at least stand 25 per cent. for several minutes, or probably long enough to drag out a dying comrade, that is, in the absence of white damp or carbonic oxide gas.

ACETYLENE.

THE COMMERCIAL SYNTHESIS OF ILLUMINATING HYDROCARBONS.*

By Prof. VIVIAN B. LEWES.

THE two methods most used in chemical science for tracing the changes taking place in matter and determining the composition of bodies are, first, the breaking up of compounds into their ultimate constituents, a process which is called "analysis;" and, secondly, the building up of the compound from the elementary matter which forms it, a process to which the name of "synthesis" has been given.

If we take chalk and heat it in the limekiln, or in the chemist's crucible, a heavy, colorless gas, called carbon dioxide, escapes from it, and leaves behind a substance which we know as quicklime. If, now, this quicklime be further acted upon by chemical methods, it can be shown to contain the metal calcium and the elementary gas oxygen, while the carbon dioxide when collected can be decomposed into the elements carbon and oxygen, and by such a series of operations as this we might perform the analysis of chalk.

If now we start with the metal calcium, with carbon, and with oxygen, it is perfectly simple to reverse the operation, and rebuild the chalk molecules from these elementary forms of matter; by burning the carbon and calcium respectively in oxygen, we obtain the quicklime and the carbon dioxide, and by bringing these substances together in the presence of moisture, chalk or calcic carbonate is once more formed, and we have synthetically built up the chalk from its constituents.

By such simple methods as these most inorganic compounds can be synthetically produced from elementary matter, but in the so-called organic chemistry it is not so easy to employ such constructive methods for the formation of compounds. Up to the end of the first quarter of this century it was supposed that organic bodies were only produced as the result of animal and vegetable life, and that their formation was due to the so-called "vital force," which was credited with governing all changes taking place in living organisms.

In the year 1828, Wohler showed that urea could be formed from cyanate of ammonium, while later on, Fownes made cyanogen by the direct combination of carbon and nitrogen, these two discoveries taken together clearly proving the possibility of forming an organic product from inorganic materials; and after this point had been reached, and the possibility of applying synthetic methods to the production of organic bodies had been demonstrated, compound after compound was built up without the aid of either vegetable or animal life, and the barrier between inorganic and organic chemistry finally broken down. Cases, however, in which such methods could be commercially successful were few and far between, as in most cases the processes which had to be adopted were costly and laborious.

In all the phenomena of ordinary combustion which we employ to provide us with heat and light, there are no compounds of greater interest than the class of organic bodies which, being formed of carbon and hydrogen in various proportions, have been termed hydrocarbons, and it is to this class of bodies that all the gases which can be used as ordinary illuminants owe their luminosity. Among the hydrocarbons, the simplest compound is acetylene, in which two atoms of carbon are united with two atoms of hydrogen; and it has long been known that, if a stream of hydrogen is passed through a globe in which the voltaic arc is produced between carbon points from a sufficiently powerful current, this gas is produced in minute quantities. It can also be formed in small quantities by the decomposition of carbon tetrachloride in the presence of hydrogen by the induction spark, while it is produced during processes of checked combustion in hydrocarbon flames. The direct combination of carbon and hydrogen in the electric arc is a true case of synthesis, and if we could form acetylene in this way in sufficiently large quantities, it would be perfectly easy to build up from the acetylene the whole of the other hydrocarbons which can be used for illuminating purposes. For instance, if acetylene be passed through a tube heated to just visible redness, it is rapidly and readily converted into benzol; at a higher temperature naphthalene is produced, while by the action of nascent hydrogen on acetylene, ethylene and ethane can be built up. From the benzol we readily derive aniline, and the whole of that magnificent series of coloring matters which have gladdened the heart of the fair portion of the community during the past five and twenty years, while the ethylene produced from acetylene can be readily converted into ethyl alcohol, by consecutively treating it with sulphuric acid and water, and from the alcohol, again, an enormous number of other organic substances can be produced. Thus acetylene can, without exaggeration, be looked upon as one of the great keystones of the organic edifice, and, given a cheap and easy method of preparing it, it is hardly possible to foresee the results which will be ultimately produced.

From acetylene we can produce all those bodies which we are accustomed to look upon as the most

important ones in our coal gas, and which, up to the present time, have never been produced from anything but coal, hydrocarbon oils, or other organic matter undergoing destructive distillation, but it has often occurred to those of us who are interested in the manufacture of illuminating gas that, as the supply of coal gets smaller, and as oil in time begins to share the same fate, some new sources for our illuminants and our fuels must be sought; and in my mind, at any rate, the synthetic production of hydrocarbons has been a day dream, which I, however, never expected to see possible on a commercial scale.

Not only was the synthetic production of acetylene in the electric arc well known, but ever since water gas has been introduced, small traces of acetylene and methane have been found in it under conditions which render it impossible that they should have been produced from any compound present in the incandescent fuel. They must, therefore, have been due to the direct combination of carbon and hydrogen, but these traces only occurred in quantities so small as rarely to amount to one per cent., and it was manifest that the production of the compounds could not take place in large quantities under influences which would immediately tend to decompose them.

In 1836, it was found that when making potassium, by distillation from potassic carbonate and carbon, small quantities of a by-product, consisting of a compound of potassium and carbon, were produced, and that this was decomposed by water with liberation of acetylene; while Wohler, by fusing an alloy of zinc and calcium with carbon made calcic carbide, and used it as a source from which to obtain acetylene by the action of water.

Nothing more was done until 1892, when Macquenne prepared barium carbide by heating at a high temperature a mixture of barium carbonate, powdered magnesium, and charcoal, the resulting mass evolving acetylene, when treated with water; while, still later, Travers made calcic carbide by heating together calcic chloride, carbon and sodium. None of these processes, however, gave any commercial promise, as the costly nature of the potassium, sodium, magnesium, or zinc calcium alloy which had to be used made the acetylene produced from the carbide too expensive.

It is now some 25 years ago since I listened to one of the Friday evening lectures, at the Royal Institution, given by Mr. Greville Williams, and in the same way that the thread of some melody lingers in one's mind, so has the concluding sentence of that lecture constantly recurred with ever increasing force—"The impossible is a horizon which recedes as we advance; and the terra incognita of to-day will to-morrow be boldly mapped upon every schoolboy's chart." The haunting dream of the possibility of synthesizing hydrocarbons commercially has, with the onward march of science, to-day become an accomplished fact.

As is so usual in the history of discovery, the factor which has endowed us with the power of doing this was not the outcome of an elaborate research, having this discovery for its ultimate goal, but was found by chance during the search for another object.

While working with an electric furnace, and endeavoring by its aid to form an alloy of calcium from some of its compounds, Mr. T. L. Willson noticed that a mixture containing lime and powdered anthracite, under the influence of the temperature of the arc, fused down to a heavy semi-metallic mass, which having been examined, and found not to be the substance sought, was thrown into a bucket containing water, with the result that violent effervescence of the water marked the rapid evolution of a gas, the overwhelming odor of which enforced attention to its presence, and which, on the application of a light, burnt with a smoky, but luminous flame.

Investigation into the cause of this phenomenon soon showed that in a properly constructed electric furnace, finely ground up chalk or lime, mixed with powdered carbon in any form, whether it were charcoal, anthracite, coke, coal, or graphite, can be fused with the formation of the compound known as calcic carbide, containing 40 parts by weight of the element calcium, the basis of lime, and 24 parts by weight of carbon, and that on the addition to this of water, a double decomposition takes place, the oxygen of the water combining with the calcium of the calcic carbide to form calcic oxide or lime, while the hydrogen unites with the carbon of the calcic carbide to form acetylene, the cost of the gas so produced bringing it not only within the range of commercial possibilities for use, per se, but also the building up from it of a host of other compounds, while the production of the calcic carbide from chalk and from any form of carbon renders us practically independent of coal and oil, and places in our hands the prime factor by which nature in all probability produces those great underground storehouses of liquid fuel upon which the world is so largely drawing to-day.

Wonderfully and intensely interesting as is the train of thought opened up by the discovery of this substance and its commercial production, the object I have in view this evening is not to discuss theoretic possibilities, but to show you the important effect which it will have in the direction of our great gas industry, and the phase of this which I wish to deal with specially is the value of acetylene, either for producing, per se, an enormously high illuminating effect, or for the enrichment of low grade coal gas.

When the calcic carbide is placed in a glass flask and water allowed to slowly drip upon it from a dropping tube, the decomposition at once commences with considerable rapidity, and the acetylene pours off in a continuous stream; as the decomposition continues, the solid mass in the flask swells up, and is eventually converted into a mass of slaked lime.

Calcic carbide is a dark gray substance, having a specific gravity of 2.262, and, when pure, a pound of it will yield on decomposition 5.3 cubic feet of acetylene. Unless, however, it is quite fresh, or means have been taken to carefully protect it from air, the outer surface gets slightly acted upon by atmospheric moisture, so that in practice the yield would not exceed five cubic feet. The density and hardness of the mass, however, protects it to a great extent from atmospheric action, so that in lumps it does not deteriorate as fast as would be expected, but in the powdered condition it is rapidly acted upon.

For commercial purposes the carbide will be cast direct from the electric furnace into rods or cylindrical cartridges, which, when 12 inches long and 1¼ inches in diameter, will weigh one pound, and will give five cubic feet of gas.

The acetylene so made, when analyzed by absorption with bromine, the analysis being also checked by determining the amount present by precipitation of silver acetylides, gives 98 per cent. of acetylene and 2 per cent. of air, and traces of sulphureted hydrogen, the presence of this impurity being due to traces of sulphate of lime—gypsum—in the chalk used for making it, and to pyrites in the coal employed.

Acetylene is a clear, colorless gas, with an intensely penetrating odor which somewhat resembles garlic, its strong smell being a very great safeguard in its use, as the smallest leakage would be at once detected; indeed, so pungent is this odor, that it would be practically impossible to go into a room which contained any dangerous quantity of the gas.

This is an important point to remember, as the researches of Bistrow and Liebreich show that the gas is poisonous, combining with the hæmoglobin of the blood to form a compound similar to that produced by carbon monoxide, while the great danger of the latter gas is that, having no smell, its presence is not detected until symptoms of poisoning begin to show themselves, so that no fear need be apprehended of danger from this source with acetylene.

Acetylene is soluble in water and most other liquids, and at ordinary temperature and pressure—60° Fah. and 30 inches of mercury—10 volumes of water will absorb 11 volumes of the gas, but as soon as the gas is dissolved, the water, being saturated, takes up no more. Water already saturated with coal gas does not take up acetylene quite so readily, while the gas is practically insoluble in saturated brine—100 volumes of a saturated salt solution only dissolving 5 volumes of the gas. The gas is far more soluble in alcohol, which at normal temperature and pressure takes up six times its own volume of the acetylene, while 10 volumes of paraffin under the same conditions will absorb 26 volumes of the gas. It is a heavy gas, having a specific gravity of 0.91.

When a light is applied to acetylene, it burns with a luminous and intensely smoky flame, and when a mixture of one volume of acetylene with one volume of air is ignited in a cylinder, a dull red flame runs down the cylinder, leaving behind a mass of soot and throwing out a dense black smoke. When acetylene is mixed with 1.25 times its own volume of air, the mixture begins to be slightly explosive, the explosive violence increasing until it reaches a maximum with about twelve times its volume of air, and gradually decreases in violence until, with a mixture of one volume of acetylene to twenty of air, it ceases to be explosive.

The gas can be condensed to a liquid by pressure, Ansell finding that it liquefied at a pressure of 21.5 atmospheres, at a temperature 0° C., while Cailletet found that at 1° C. it required a pressure of 48 atmospheres, the first named pressure being probably the correct one. The liquid so produced is mobile and highly refractive, and when sprayed into air, the conversion of the liquid into the gaseous condition absorbs so much heat that some of the escaping liquid is converted into a snow-like solid, which catches fire on applying a light to it, and burns until the solid is all converted into gas and is consumed.

In my researches upon the luminosity of flame, I have shown that all the hydrocarbons present in coal gas and other luminous flames are converted by the baking action taking place in the inner non-luminous zone of the flame into acetylene before any luminosity is produced, and that it is the acetylene which by its rapid decomposition at 1,200° C. provides the luminous flame with those carbon particles, which, being heated to incandescence by various causes, endow the flame with the power of emitting light. The acetylene, being in this way proved to be the cause of luminosity, one would expect that in this gas we have the most powerful of the gaseous hydrocarbon illuminants; and experiment at once shows that this is the case.

Owing to its intense richness, it can only be consumed in small flat-flame burners, but under these conditions emits a light greater than that given by any other known gas, its illuminating value calculated to a consumption of 5 cubic feet an hour being no less than 240 candles.

ILLUMINATING POWER OF HYDROCARBONS FOR A CONSUMPTION OF FIVE CUBIC FEET OF GAS.

	Candles.
Methane.....	5.2
Ethane.....	35.7
Propane.....	56.7
Ethylene.....	70.0
Butylene.....	123.0
Acetylene.....	240.0

Having arrived at this startling result, it will be as well to at once turn to the commercial aspect of the problem, as it is upon this that the utilization of this magnificent illuminant is entirely dependent. At the present time, private information from America shows that calcic carbide can be produced at a little under £4 a ton, and the beautifully pure lime obtained by the decomposition would be worth to the gas manager at least 10s. a ton; and as a ton of the carbide will give rather more than 1¼ tons of quicklime or 1½ tons of slaked lime, £3 10s. may be taken as the cost of the acetylene produced from a ton of the material, and will leave a margin for handling. A ton of the carbide will yield in practical working 11,000 cubic feet of acetylene, which will bring the cost of the gas out at 6s. 4½d. per 1,000.

The cheapest and best enrichment process known at the present time is that introduced by Mr. Young, and which has been adopted at a number of gas works in Scotland and the north of England. In this process, by special methods of retorting, oils are decomposed to yield a rich gas, which, in the photometer, and burned in suitable burners, per se, gives an illuminating value of about 60 candles, but for which an enrichment value of 96 candles is claimed.

I am desirous of understating, rather than overstating, the powers of the acetylene, so that, instead of taking enrichment values for which it might be questioned, I prefer to simply take the illuminating power of the gas when burned, per se, and the light meas-

* A paper read before the Society of Arts, London.—From the Journal of the Society.

ured in the photometer, which, as before stated, is 240 candles, while, for the same reason, we will take the claimed enrichment value of the Young gas, instead of its photometric value.

An extended experience, gained with the Young process, as used at St. Helen's for the enrichment of coal gas, shows that the cost may be taken at 3s. 4d. per 1,000 cubic feet. If now we compare this with the acetylene at 6s. 4½d. per 1,000, we find that the 240 candle gas at this price would be equal to Young gas at 2s. 6½d. Moreover, the Young plant, to work a ton of oil per diem, costs—according to the experience at Peebles—£1,500, and generates 22,000 cubic feet a day, the retorts for this purpose occupying a very considerable space; while, to make the same volume of acetylene, two tons of material would have to be handled, and the whole operation could easily be carried out in one small egg-ended boiler, fitted with an automatic water feed and automatic gas delivery valve to outlet of the main for the holder, so that the enriching gas could be added pro rata to the gas as it left the works in order to bring it up to any required strength, in the same way as is done with the Maxim-Clarke enrichment, and all the troubles of stratification in the holder would be done away with. For the first few hours the water in the consumers' meters would absorb small quantities of the acetylene, but quickly becoming saturated, no farther absorption would take place.

It is well known that acetylene forms two compounds with ammoniacal solutions of the metals silver and copper, and both of these compounds, when dry, can be readily exploded by percussion, friction or heat. In the early days of gas supply, copper pipes were used in New York, and Torrey, in 1839, found in them a brown sealy deposit, which exploded when struck or heated to 200° C., and which was, in all probability, acetylde of copper.

An extended series of experiments on this point show that when metals are kept in the gas, even if moisture be present, no action takes place unless water condenses on the metal, when tarnishing with silver and copper, and to a less degree with brass, commences, and under these conditions, an acetylde of mercury can also be formed, but the other metals remain unacted upon. If, therefore, iron, tin, lead or compo pipes be used for the gas supply, no precautions are necessary. Copper and brass tubes must either be coated inside with some varnish not acted upon by the acetylene, or tin lined.

In America, which was the birthplace of this method of making calcic carbide, the acetylene is mixed with an equal volume of air, and the mixture burnt at small slit burners; but I confess to a grave mistrust of this method of using the gas, as the margin of safety in the amount of air required to convert the mixture into an explosive is so small that the danger of exceeding it on any large scale must be very great, as any mistake or alteration in the mixing apparatus used for this purpose might easily bring the percentage of air up to the explosive limit, while the diluting action of the nitrogen of the air reduces the illuminating value of the acetylene present from 240 candles to 130.

The possibility of liquefying acetylene by pressures about those at which liquid carbon dioxide is produced so largely enables enormous volumes of this gas to be compressed into the liquid state in small wrought iron or steel cylinders, and in this condition, by means of suitable reducing valves and burners of the right construction, it may be stored and burnt. Used in this way, it will be of the greatest possible value for floating buoys, and the small cylinders can also be arranged in the form of portable lamps, while for use in the country, where no gas is available, a large cylinder of the liquid gas placed in an outhouse would supply a country house with light for a very long period; and there is no doubt that there is a very great field for it in this direction, as by utilizing suitable burners a consumption of half a cubic foot an hour will give a light equal to from 20 to 25 candles.

Perhaps the most valuable suggestion which has been made with regard to the utilization of this remarkable method of making acetylene is, that advantage should be taken of the method of preparation to utilize the body of portable lamps for dining and drawing rooms in places where no gas supply exists. To do this a strong steel cylinder, 4 inches in diameter and 16 inches in length, is fitted with an opening in the top of such size that a pound cartridge, or stick of the calcic carbide, can be passed through it. The cylinder has a second opening at the bottom, closed by a screw, for cleaning out the lime left by the decomposition. The right proportion of water is put into the cylinder, and the stick of carbide, coated with a slowly soluble glaze, is inserted and the head of the lamp screwed on. This head contains a double reducing pressure valve, which brings down the pressure existing in the cylinder to that necessary for the proper consumption of the gas, it also being fitted with a valve. As the glaze dissolves from the surface of the stick of carbide, acetylene is generated, and the five cubic feet are compressed by their own pressure, the cylinder being placed in a vessel of cold water while the gas is generating, and the gas can then be burned from a suitable jet at the rate of half a cubic foot per hour, which will give a light of over 20 candles for something like 10 hours. When the gas is all burnt out from the cylinder the top of the lamp is screwed off, the bottom plug also removed, and the lime washed out from the interior of the cylinder by a rapid stream of water. The cylinder is then recharged as before. Used in this way also, this gas would rapidly replace oil gas for railway lighting, as the fittings at present in use for the Pope and Pintsch systems would answer perfectly well for the purpose of using acetylene, the only difference being that the cylinder placed below the carriage, which, under the present conditions, is filled with compressed oil gas, would be utilized, not only as a storing, but as a generating vessel for the acetylene, the highly expensive oil gas manufacturing and pumping plant being done away with, and a magnificent illumination insured in the carriage.

Of late years, an idea has been slowly permeating the minds of some gas managers in this country that it might be well to adopt a dual gas supply, one for fuel purposes, which would consist of a poor coal gas of about 12 candles, while the gas for illuminating purposes would be of about 20 candles; and in one town, at least, it has been proposed, and, I believe, carried

out, that a supply of poor quality coal gas should be sent out during the day, when the maximum consumption is for heating purposes, and a richer gas at night for illuminating purposes, utilizing the same mains for both. Although this is possible in a small town where the area to be supplied is not large, it would be impossible in a big town where many miles of huge mains have to be traveled before certain districts are reached, and the cost of a double set of mains would render a dual supply an impossibility.

The use of acetylene would render it possible for the gas company to send out a 12 candle gas for heating purposes, both by night and day, while a small enrichment cylinder might be attached to the gas outlet pipes from the consumer's meter, and this would be made to automatically enrich the gas supplied to his house, so that by setting a valve he could have any quality he might desire.

The economic value of an illuminant such as acetylene becomes apparent, when we compare the cost of the gas for equal illumination with the light obtained from other illuminants. The London gas has an illuminating power of 16 candles, while the acetylene has an illuminating value of 240 candles, and this, at 6s. 4½d. per 1,000, would in light-giving value be equivalent to London coal gas at less than 6d. per 1,000.

In order to obtain a given illumination, moreover, the volume of gas to be consumed is excessively small, as compared with any other illuminating gas, and the products of combustion are reduced to an excessively low limit. One hundred cubic feet of London coal gas will yield 50 cubic feet of carbon dioxide, and 140 cubic feet of water vapor, as the products of its complete combustion, while 100 cubic feet of acetylene would yield 200 feet of carbon dioxide and 100 feet of water vapor. The acetylene, however, in its combustion, gives a light of 240 candles, as against 16 yielded by the coal gas; and for equal illumination, therefore, the amount of carbon dioxide and water vapor produced is enormously smaller.

The following table contrasts the products of combustion evolved from London coal gas, when consumed in various forms of burners, and giving an illumination of 48 candles, which may be presumed to be the amount of light required in a fair-sized London dining room, and contrasted with this is the amount of the products of combustion which acetylene would evolve in giving the same amount of light; while to make the meaning clearer, I have added the number of adults who would exhale the same amount of carbon dioxide in the same time.

Burner.	Gas consumed.	Carbon dioxide produced.	Adults.
Flat flame, No. 6.....	19.2	10.1	16.8
Flat flame, No. 5.....	22.9	12.1	20.1
Flat flame, No. 4.....	25.3	13.4	22.3
London Argand.....	15.0	7.9	13.1
Acetylene.....	1.0	2.0	3.6

If we obtained the same amount of light from paraffin lamps, the carbon dioxide evolved would be equivalent to 22.5 adults; while as far as carbon dioxide goes, you might as well invite 32.7 guests to dinner as use 48 sperm candles to supply the needed illumination.

The flame of acetylene, in spite of its high illuminating value, is a distinctly cool flame, and in experiments which I have made by means of the Le Chatelier thermo-couple, the highest temperature in any part of the flame is a trace under 1,000° C., while coal gas burning in the same way in a flat-flame burner the temperature rises as high as 1,360° C. If the heating effect of the flames be contrasted for equal illumination, it will be seen that the acetylene flame has so small a heating effect, considering its area, that it would not be much greater than the ordinary electric incandescent lamp.

The intensity of the light will make small acetylene lamps of enormous value for lantern projection, for railway signals, and, coming down to smaller things, bicycle lamps, while I should imagine the ease of production specially adapts it for such purposes as light-house illumination.

The scope and possibilities of such a discovery as that which I have brought before you this evening cannot be realized until many factors, at present unknown, are thoroughly worked out, and you must remember also that the time at my disposal has only enabled me to bring before you to-night some facts connected with the light-giving value of this hydrocarbon, and that, as a stepping stone to the synthesis of other bodies, its value will be incalculable. One cannot help feeling that as science grows, and as our grasp and comprehension of the marvelous processes by which nature builds up her matter become more and more extended, synthesis may have even greater conquests to make than the mere building up on a commercial scale of an illuminating hydrocarbon.

We are beginning to realize more and more fully the marvelous way in which nature keeps matter in circulation, the way in which animal and vegetable structures are built up from the simplest and most plentiful substances, and the way in which, when the structure is done with, those processes of slow combustion, which we call decay, again convert the waste bodies into carbon dioxide and water vapor, from which once more nature reconstructs the vegetable and animal kingdom; and it may be that as our perception of the methods of that marvelous natural architecture gets clearer and keener, we may discover how, by simple synthetic processes, the carbon dioxide and water vapor, which form Nature's building material, may be synthetically utilized by us in building up, not the perfected form of man, or animal, or plant, but the building on a commercial scale of the food which is required by Nature for carrying on the functions necessary for life.

DISCUSSION.

Mr. Lewis G. Wright said this paper was of much interest to technical men, in two points of view, because most of them had an interest in both the scientific and commercial side of any such process as had been described. He would ask whether it had been proved by experiment that the high luminosity of

acetylene was retained when mixed with coal gas as an enricher, to the same extent as it showed when burned in the pure condition. Many, perhaps, might think that such would necessarily be the case, but he had reason to know that in mixtures of gases the luminosity was not always the arithmetical mean of that of the gases employed.

Mr. Wm. Sugg said the whole thing was so surprising that it was very difficult to offer any remarks upon it. He was much struck with the fact that this gas appeared to have such a strong affinity for oxygen. It was generally found very difficult, in burning a very rich gas, to provide it with a sufficient quantity of oxygen from the air to produce a brilliant light; but this appeared to burn as brightly almost as if it were in an atmosphere of oxygen. There did not appear to be anything very special about the burner, and, therefore, he gathered that the gas must have a powerful affinity for oxygen. The manufacture of the gas appeared so simple that probably most of those present thought they could do it straight off, but possibly some difficulties might crop up in practice.

Mr. C. C. Carpenter (Southwark and Vauxhall Gas Company) said he must congratulate Prof. Lewes on this sequel to his well-known researches into the effect of acetylene on the luminosity of gas. He should also like to emphasize the point raised by Mr. L. Wright with regard to the enriching power of acetylene. Another point which occurred to him was with reference to the production of the calcic carbide at the price mentioned. It seemed to him that that was very low for an article which could only be manufactured by the electric furnace, and he should be glad to know if any light could be thrown on the method of producing the electricity which formed the carbide. The whole thing hinged on the commercial aspect, and that depended on the cost of the material. At any rate, he thought Prof. Lewes had done something which would be a great relief to the electric light engineer, as he would be able to get a level load line by making an article which would serve for the manufacture of gas.

Mr. T. S. Lacey said many people thought the Young process should be more largely adopted by gas companies, on account of the cheapness of the gas produced; but with a rich gas, such as was made in London, the amount of enrichment was but a small percentage of the total value of the light, and that portion varied considerably. Sometimes you had to add one candle, sometimes two, sometimes half, and sometimes nothing, and the result was you were obliged to have a plant equal to the maximum enrichment, which was equal to the use of ten or fifteen per cent. of cannel; that meant a very large capital outlay. Any plan, therefore, which removed the necessity of such outlay was of great importance.

Mr. J. W. Helps said the paper had been very interesting, and he hoped it would prove of great value to the gas industry. Prof. Lewes said that acetylene would be used for enrichment much in the same way as the Maxim-Clarke process, i. e., it would be applied to the gas after it left the holders, and he should like to know if it would have any effect on the absorption of naphthalene, in which direction some enriching methods were found to be useful. He also thought the cost of the carbide was very low for an electric furnace product, and should like to know if the figures given were not based on electricity produced by water power.

Mr. Frank Mead said the paper had been quite a novelty to those connected with the gas industry, and was of intense interest. The main point, no doubt, in the commercial aspect, was the cost of the carbide. If it were produced as a by-product, one could understand its being sold at a low price; but could it be produced at £4 a ton if an electric furnace were employed for that sole purpose? If the process were generally adopted, the quantity required would be very large, and what effect that would have on the price it was rather difficult to say. This gas, when unburned, was said to have a remarkably unpleasant odor, which would make its presence evident, and prevent danger; but he would ask if there were any odor when it was burned. He did not see any reason why there should be an odor from its combustion, but the point deserved attention. Again, as there was a great difference between the specific gravity of this acetylene and that of ordinary coal gas, he thought there might possibly be layering of the two gases when mixed. The mixture with the gas as it went away from the holder was, of course, a different thing from mixing the enricher with the gas in the holder.

Mr. Frank Wright said it was very gratifying to find that electricity was, to some extent, trying to befriend gas, as in certain instances the reverse had been the case. He should like to ask Prof. Lewes if he had any information as to the candle power to be obtained by this gas per horse power of electrical energy, because, it seemed to him, it would hinge on that. If the gas companies did not take it up, the electrical concerns might work it round in a happy cycle of synthesis and analysis.

Mr. H. O'Connor asked what would be the effect of mixing acetylene with water gas. If it did not produce an explosive mixture, the smell given off by the acetylene might give to water gas the much needed quality of notifying its presence when escaping.

Mr. R. Manuel asked if there would be any danger of an explosion if an escape of acetylene took place in a room, and a person afterward went in with a naked light, and if so, would it be more severe than an ordinary gas explosion?

Prof. Lewes, in reply, said when he saw Mr. Lewis Wright get up, he fully expected to hear a question directed to some vital point. The question of enrichment was one of the most complex one could deal with, and enrichers varied to an extraordinary extent. An enrichment curve was never a nice, even curve, in which one, two or three per cent. increased the illuminating value in proper proportion. You always had a curve rather flat at the bottom, and then gradually increasing up to the proper point. He was at present working out the enrichment values of a large number of pure hydrocarbons and mixtures, and was gradually getting to the bottom of the secret, but those results must be reserved for another paper. He might say, however, that when acetylene was added in small quantities to coal gas, the enrichment value was about one and one-half candles per cent. at the bottom of the curve, and went up fairly rapidly until

you got to fifty candles, when it was at about its maximum. It was the same with ethylene, ethane, and several others. For water gas, however, it was of hardly any value as an enricher. If you took pure water gas, consisting of carbon monoxide and hydrogen, with small traces of impurities, ten per cent. of the acetylene mixed with it gave a non-luminous flame. He knew the reason of that, and it made it absolutely useless for the enrichment of gas of that character. The same thing was found by Dr. Percy Frankland with ethylene. The burning question, next to that of enrichment, was the price of the carbide. He believed the experiments quoted in America, from which the price of fifteen dollars was obtained, were made with electricity derived from water power; but there was another point to be borne in mind. Acetylene was not only a benefactor to the gas world, but it might be a benefactor to the electric world. The big installations which were erected for lighting purposes could only use their plant for about one-fifth of the day, and they were trying to make dividends in the face of that obstacle. They all knew what happened to plant which stood still for four-fifths of its life, and he ventured to think that when there was a market for calcic carbide many of the big producing stations would look upon it as a help rather than an enemy. If electric lighting were all in the hands of one corporation, they might think it worth while to try and stifle this, if they thought it was going, from its illuminating value, to interfere with them, but there were many corporations all struggling to show good returns, and if they could use the leads from the dynamos for an electric furnace during daylight and for the generation of light during the night, there need be no fear of getting a sufficient supply of electricity for this purpose at a reasonable price. In reply to Mr. Sugg, he might say that the luminosity of a flame was not due entirely to the affinity of hydrocarbons for oxygen; it depended on exceedingly complex chemical reactions, of which a few only had yet been thoroughly worked out; and, in fact, the acetylene flame, though so brilliant as to suggest the highest incandescence, was far cooler than that of an ordinary gas burner. The temperature of an ordinary sixteen-candle gas flame in some parts rose as high as 1,400° C.; but no part of the acetylene flame was much over 900° C. There was no overheating of the room, and the products of combustion were not noxious. If there were incomplete combustion, the flame would smoke so that you would have to turn it out, and with such incomplete combustion only would there be any smell. The products would be the same as from the complete combustion of coal gas—carbon dioxide and water vapor. The plan he should recommend in using acetylene as an enricher would be to introduce it by a regular flow into the outlet main. Mr. Lacy raised an important point with regard to enrichment. In London there was a monstrous waste of enrichment, and the gas was sent out considerably above the statutory limits in order to avoid any chance of a change of temperature bringing down the illuminating power, and so rendering the company liable to penalties. There ought not to be that necessity, and any process which required such a large margin was a wrong process. They needed that margin because they employed vapors to a considerable extent, and had to allow for skin friction in the mains, which was more important even than cold in bringing them out again. If acetylene were used, the gas might be sent out at 16.4 or 16.5 candles, and there would not be any chance of its losing its illuminating power, because they would be dealing, not with a vapor, but with a fixed gas. Acetylene would have no effect on naphthalene. The vapor of liquids had somewhat the solvent effect that the liquids themselves had, and that was why the vapors of some of the light hydrocarbon oils dissolved and moved on the naphthalene. He should put the relation between candle power and electrical horse power in this way: the light obtained from one horse power of electric energy, by means of an incandescent lamp, might be put at twenty-eight, and by means of the production of calcic carbide and acetylene at forty-four.

The chairman, in proposing a hearty vote of thanks to Prof. Lewes, said they were much indebted to him for showing how an ornamental gas works might be constructed, apparently at much less cost than the present structures, which by no stretch of imagination could be called ornamental. Another thing that struck him was that they seemed to be getting very near that great desideratum in electrical engineering, a level load line, by means of a new form of storage battery. The electric energy in the furnace came out in the form of a stick which could be carried about, and would give a certain quantity of brilliant light, whenever you put it into water; so that really it was a case of storage of electricity in an extremely convenient form. It appeared to him not at all impracticable that, after all, the best way of utilizing electricity would be to convert it into light by the method which had been exhibited that evening.

MECHANICAL BOTTLE CARRIER FOR GLASSWORKS.

How hard in some of its details is the labor of glassworkers, who are submitted to the high temperatures that are due to the large melting furnaces, is well known. So an endeavor is made to substitute well elaborated mechanical methods for manual labor, properly so called, in all cases where it is practicable. Thus, Mr. Houtart, a glassworks foreman of the North, who is at the same time a distinguished philanthropist, has just introduced into the equipment of ovens for annealing bottles an interesting improvement whose details have been communicated to us by Mr. J. Sagnier, a former student of the Central School. The process usually employed is as follows:

The bottles as they come from the hands of the blower must be carried to the annealing oven, wherein they cool slowly, else otherwise they would break. To this effect, they are, in the first place, arranged in an iron mould provided with a handle in the form of an iron rod. The office of bottle carriers is performed by children. Now, on the one hand, the new laws concerning labor render the recruiting of these children difficult, and, on the other, from a humanitarian view-point, these children perform an operation that has justly attracted Mr. Houtart's attention.

In fact, while the blower is preparing a new bottle in the mould, the child must take away the punty rod that has been used in the preceding operation, bring a new cooled rod, introduce into the bottle mould a shaving of wood in order to prevent the bottle from adhering to the mould, and finally oil the pipe with which the blower shapes the bottle.

In the hot atmosphere of the works, the child who performs all these little operations goes and comes always on a run, shod with large and heavy wooden shoes in order to avoid wounds from the fragments of glass. After a good blower has blown his six hundred bottles in a day, the little carrier has made 1,200 trips, to and fro, between the blower and the oven, and has also taken away and brought back the punty rod 1,200 times, the total distance traveled in this hot work often being twelve miles. Grown up men themselves do not stand the work very well, and, what is surprising, not so well as children.

Nothing but a mechanical device could put an end to this hard labor. Such a one has been combined by Mr. Houtart, but it was not without trouble that he caused it to be adopted. It was necessary to struggle not only against technical difficulties, but also against an inveterate routine, the worst of difficulties. It was necessary in the very first place to render the continuous annealing oven practically utilisable, for, in the old way, a special annealing oven received and annealed all the bottles blown by all the blowers during the day's work; and every blower had his own unvarying station from which he could not be removed. Had the position of the annealing oven varied from day to day, it would have been necessary to have a mechanical carrier in attendance, as it were, every day, and to what an expense and complication that would have led may well be imagined.

The continuous annealing oven has, as we have said, caused this first difficulty to disappear. It permits of making use of a single oven and of a single mechanical carrier. The following is a brief description of it which our engraving will permit of being perfectly understood.

At aa, in front of each blower, there are iron plate receptacles lined with hard wood, in which the blower

A NEW ELEMENT IN THE NITROGEN GROUP.

By A. E. TUTTON.

A NEW element appears to have been discovered by Dr. Bayer in the residual liquors derived from the older process for the extraction of aluminum from red bauxite, and an account of it is communicated to the current issue of the Bulletin de la Societe Chimique. The liquors in question consist chiefly of sulphate and carbonate of sodium, but there are also present considerable quantities of chromic and vanadic acids, and smaller quantities of molybdic, silicic, arsenic, phosphoric, and tungstic acids, together with alumina, magnesia, and lime, and an acid of the new element. In order to isolate the latter, the vanadium and chromium are first removed, the former as the difficultly soluble ammonium vanadate, and the latter as hydrated sesquioxide. The filtered liquid is then saturated with sulphureted hydrogen, and the sulphides, all of which are soluble in the alkaline liquid, are precipitated by hydrochloric acid. This precipitate exhibits a deep brown color, due to the new element. When dried it presents a brown earthy appearance, and burns readily with evolution of sulphur dioxide and formation of a bright brown powder. Concentrated nitric acid instantly causes ignition, and formation of a deep brown solution, from which a small quantity of a yellow precipitate of a compound of molybdic and arsenic acids is deposited. The brown liquid contains no tin, antimony, or tellurium, but still retains traces of vanadium, molybdenum, and selenium. These elements are best removed by calcination of the sulphides immediately after their precipitation with hydrochloric acid when selenium is volatilized, treatment of the residue with ammonia and ammonium nitrate, which precipitate the last traces of vanadium as ammonium vanadate, and concentration of the filtered liquid which causes deposition of ammonium molybdate. During the concentration two distinct crops of different crystals are obtained, the first and most sparingly soluble being cubic crystals of an olive-brown color, and the second the much more soluble ammonium molybdate. The olive-brown cubic crys-

APPARATUS FOR CARRYING BOTTLES TO THE ANNEALING OVEN.

deposits the bottle that he has just finished. Beneath these holders pass receivers, BB, which likewise are of iron plate containing a bed of wood and which are set in motion by a belt, M, guided by a pulley, Q. The pulley, R, transmits motion through gearings, S, to another pulley, Q, back of the frame of the carrier.

The receivers, provided with a pendent rod, N, oscillate upon a pivot at right angles with their long axis. The rods holding the supports and connecting them with the belt, M, are guided by a steel cross bar which rests upon two cheeks, B, between which the belt runs.

The bottle is deposited by the blower at a. The side, B, of the holder, movable around a joint whose axis is ZT, is carried back to its normal position by a counterpoise. The receiver, B, passing beneath the holder, lifts the counterpoise. The side, T, opens and the bottle falls upon the wooden bed of the receiver. This bed inclines slightly backward, and the receiver is then able to pass under the other holders, a, without opening them. It continues on its way toward the point, A, situated opposite the door of the oven. Having arrived here, it tilts, carried along by the rod, N, and the bottle slides down an inclined plane and enters the oven in which it is to be annealed.

Let us add that a kick of an ingenious pedal by the blower greases the pipe through the intermedium of an oiled dabber, as was formerly done by a boy, and places automatically in the bottle mould the shaving of wood designed to prevent the melted glass from adhering to the iron.

Such are the results realized by this ingenious mechanical installation, which is to the praise of the glassworks foreman, who has prepared it by a profound study of every detail. It constitutes a short chapter in the protection of childhood in the laborious life of the manufactory, and will contribute toward preserving healthy and vigorous subjects for the industry without exhausting them at the period at which the human organism is developing, and at which it has special need of being spared. It is a useful and remarkable example of the application of machinery, which is too often called in question, with an absolute ignorance of the services that it must forcibly render as soon as any industry has reached a certain stage of progress and a limit beyond which primitive methods no longer assure either the requisite amount of necessary work or the just needs of the most elementary hygiene.—La Nature.

tals contain the new element, together with a little molybdenum. The latter is readily removed by dissolving the crystals in dilute hydrochloric acid, and passing a current of sulphureted hydrogen through the liquid heated to about 70°. The new element is not precipitated by sulphureted hydrogen in an acid solution. The filtered liquid is then allowed to evaporate in the air. At first it is bluish-violet in color, and contains the new element in a low state of oxidation; subsequently it becomes oxidized, and the color changes to lemon yellow. The oxide in the latter stage possesses marked acid proclivities, and probably corresponds to the formula R_2O_3 . The acid itself is soluble in water, from which it is deposited in yellow crystals, which at a red heat fuse to a brownish yellow mass. Ammonia transforms the acid into a crystalline powder of olive color, presumably an ammonium salt, which readily dissolves in hot water and crystallizes from the solution in cubes on cooling. The solution is olive green, and is precipitated by strong ammonia. The solution of the acid after reduction with sulphureted hydrogen in presence of hydrochloric acid yields with ammonia a voluminous deep violet-brown precipitate, which rapidly becomes crystalline. The precipitation is not complete, hence the supernatant liquid is colored violet. Caustic soda and sodium carbonate likewise incompletely precipitate it, owing to solubility of the precipitate in excess of the reagent with formation of a soluble salt. Chlorides of barium and calcium produce grayish-violet precipitates of the salts of those metals.

An especially interesting reaction is that with ammonium sulphide, with which the highly oxidized yellow solution of the acid yields a deep cherry-red coloration, due to a sulfo-salt. Acids precipitate from this solution a sulphide of the color of iron rust. Silver nitrate produces a green precipitate of the silver salt, soluble both in nitric acid and in ammonia, and if the solution in the latter solvent is effected at a moderately elevated temperature, the silver salt is deposited in crystals upon cooling. Magnesia mixture gives, after standing a few minutes, a green precipitate analogous to ammonium magnesium phosphate, and, owing to the slowness of the precipitation, the latter occurs in the form of relatively large crystals; moreover, the precipitation is complete after a short time, for the liquid which at first is green becomes colorless. A yellow precipitate is likewise afforded with a nitric acid solution of ammonium molybdate, as in the case of phosphoric acid. The chlorides of the new element