

conduction is very small. Of course, if part of the flame through which the glass-coated wires pass is at a higher temperature than the portion around the twist, as the heat penetrates the glass it will give too high a reading, but for the first thirty or forty seconds there is no fear of this.

With this arrangement I was able to map out the temperatures existing in the flat flame, in which I had traced out the changes taking place in the constituents of the gas; and I found that the temperature rapidly rose from 500° C. half an inch above the burner to a little over 1,200° C. at the commencement of the luminous zone—the luminous edges having a temperature of 1,216° C.; and these temperatures were further increased in the luminous zone, until near the top of the flame 1,368° C. was reached. This at once gives us the secret of the luminosity. From the mouth of the jet and up to a temperature of 1,000° to 1,200° C., we have the formation of acetylene from the original hydrocarbons; but the moment the requisite temperature is reached by the combustion of the hydrogen and the carbon monoxide, the acetylene decomposes with a further rise of temperature, and the carbon, heated to incandescence, radiates heat and light.

In the experiments with the hydrocarbons the gases were passing through a heated space six inches long kept at a constant temperature; in the flame they are passing through a space 1.75 inches long with a rapidly increasing temperature, so that instead of the acetylene becoming polymerized to any great extent, it reaches a temperature at which dissociation takes place almost immediately it is formed.

Experiments with hydrogen-borne benzene vapor show that at a temperature of 1,200° to 1,300° C. it is reconverted to acetylene, and this then at once breaks down to carbon and hydrogen, and the same happens with any other heavy vapors formed in the inner zone, and these bodies formed probably in minute quantities by polymerization, together with any remaining methane, are reconverted into acetylene and deposit their carbon as soon as the necessary temperature is reached, and this supplies a fresh quantity of carbon particles to the upper portion of the luminous zone, and so increases its size.

The careful analyses of Hilgard, Landolt, and Blochmann, made to determine the interactions taking place in various flames, are in their main features in close accord with a long series of analyses of the flame gases which I have made, and one of the most striking features of these is the comparatively slow rate at which the heavy hydrocarbons disappear, as compared with the other constituents of the original gas. This I find to be chiefly due to diffusion, which causes the hydrogen and methane to find their way to the outerskin of the flame first, and it is these bodies, therefore, which bear the brunt of the earlier combustion and yield the heat which bakes the heavy hydrocarbons ascending straight upward from the burner into acetylene.

If three concentric tubes be placed half an inch above an open tube from which coal gas is issuing, and the gas from each is withdrawn and analyzed, it will be found that on comparing them with the original gas the action is most marked. The gas in the outer tube being practically a mixture of air with hydrogen and methane and no heavy hydrocarbons, while in the inner tube the unsaturated hydrocarbons have risen from 3.56 to 4.53.

All analyses of the flame gases also show that the hydrogen burns first, and that next in rapidity of burning is the methane, and Prof. Smithells advances the theory that in the incomplete combustion taking place in the flame the hydrocarbons burn to carbon monoxide and hydrogen.

As has been already shown, the proportion of heavy hydrocarbons consumed before conversion into acetylene and then dissociation into carbon and hydrogen is very small, and the principal hydrocarbon undergoing combustion in the flame is methane. The analyses of Landolt, Hilgard, Blochmann, myself, and Smithells all show that a large increase in the carbon monoxide undoubtedly does take place; the higher one ascends in the flame until the luminous portion is reached, and also it is probable from the same analyses that hydrogen is generated by some action in the outer layer of combustion, as in spite of its rapid combustion at the base of the flame, as shown by the large percentage of water vapor formed there, it keeps reappearing for some little distance up the flame, and it is to explain the joint appearance of carbon monoxide and hydrogen that Prof. Smithells brings forward the theory that carbon burns to carbon monoxide, setting the hydrogen free from the hydrocarbons.

There is not the slightest doubt from the work done by Dalton, Blochmann, Kersten, E. von Meyer, and Dixon, that if you explode together gaseous hydrocarbons with a limited supply of oxygen, you obtain carbon monoxide and hydrogen, and it is also probable from H. H. Baker's experiments that carbon burns first to carbon monoxide, but I fail to see that any such theory is necessary to explain the actions taking place in a flame. If we analyze the gases present in the flame $\frac{3}{4}$ of an inch above the burner, which is about the point at which increase of carbon monoxide commences, although it is not marked until $1\frac{1}{2}$ inches up the flame, we find that in the outer zone of the flame we have—

Water vapor..... 24.65 per cent.
Methane..... 8.35 "

A little deeper in the flame we get—

Water vapor..... 17.94 per cent.
Methane..... 21.51 "

and from this point up to $1\frac{1}{2}$ inches you have the temperature rapidly rising from 750° C. to 1,100° C., and it is a well-known fact that if heavy hydrocarbons and water vapor are heated together they yield carbon monoxide and hydrogen; indeed it is the most expensive method of making water gas, and wrecked one process for the manufacture of illuminating water gas, and one would expect the same thing to happen when methane and water vapor are heated to this temperature.

In order to try if this were so, methane was passed through water just below the boiling point and then through a tube heated to 1,000° C., the resulting gases being then analyzed, when it was found that the methane and water vapor had interacted to form hydrogen, carbon monoxide, and carbon dioxide, and I should

think that this is a far more likely cause of the effects produced in the flame.

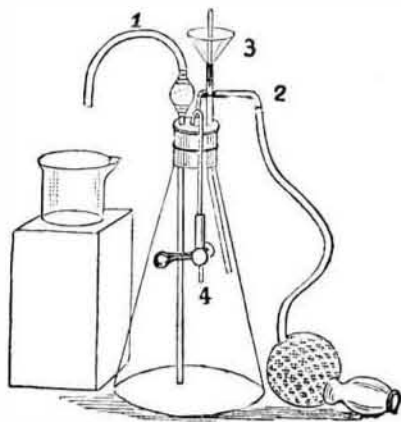
Taking the facts which I have now laid before you, we may, I think, fairly fully explain the actions that take place in the flame and lead to luminosity. As the gas leaves the jet, the hydrogen rapidly diffuses to the outer edge of the flame and burns, the methane doing the same but rather more slowly. The combustion of these gases raises the temperature 500° C. in the first half inch, while before another half inch has been traversed 1,000° C. is reached, and the chemical changes in the hydrocarbons are progressing rapidly, the unsaturated hydrocarbons and higher members of the saturated hydrocarbons being rapidly converted into acetylene. If the temperatures of the flame were not allowed to rise above 1,000° C., this acetylene would be nearly all polymerized into benzene, naphthalene, diphenyl, and other complex bodies, which would be slowly burnt up without liberation of carbon, and a non-luminous flame would result. In the case of a gas flame, however, instead of remaining at 1,000° C. the temperature rapidly rises to 1,200° C., with the result that, instead of polymerizing into more complex bodies, most of the acetylene formed at once splits up into carbon and hydrogen, and the former heated to incandescence by combustion gives the luminosity. It is the attainment of this temperature that marks the limit of the non-luminous zone. If this were the only action, however, the luminous zone would be very short. The bodies, however, formed from the acetylene before 1,200° C. was reached, and the methane, of which some still remains unburnt, are converted into acetylene at a still higher temperature, i. e., 1,300° C., and this, being reached near the top of the luminous zone, yields a fresh supply of carbon, and so increases the height of the light-yielding portion of the flame.

In producing the luminous flame, therefore, there are two main factors to be observed: first, to use such compounds as shall be most easily converted into acetylene, and secondly, to attain as quickly as possible as high a temperature as practicable.

A FILTER FOR "MAYER" ESTIMATIONS.

By F. C. J. BIRD.

WE have a conical flask fitted with a rubber cork, through which passes tube 1, shaped as shown, the bulb being filled with asbestos; 2 is the bellows of a spray producer, and is connected with a tube which passes into the air space of the flask. In 3 we have a



funnel closed with a stopper, the limb of the funnel being bent to an angle and diagonally as shown. The fourth tube (4) is closed with a burette clip. In working, the "Mayer's" solution is run in through the funnel into the alkaloidal solution until precipitation apparently ceases; then some of the mixture is squeezed out with the bellows through tube 1, thus enabling the operator to judge, by testing the clear liquid driven into the beaker, whether the end point has been reached or not.—*Chem. and Drug.*

THE PRODUCTION OF HEATING GAS AND AMMONIA.

By A. HENNIN, M.A.I.M.E.

IN the dry distillation of coal, the production of ammonia does not exceed 10 per cent. of the total nitrogen, being limited by the water of combination of the coal. This conclusion is corroborated by the fact that in blast furnaces where raw coal is used, although all the coal is consumed, and consequently all the nitrogen is liberated, the product of ammonia does not exceed 15 per cent. of the total nitrogen. In addition to the water of combination in the coal, there is doubtless also a proportionate effect, due to the water of combination of the iron ore and flux, perhaps slightly influenced by traces of water carried into the furnace with the air blast.

If all the nitrogen in coal could be converted into ammonia, a coal containing 1½ per cent. of nitrogen would produce per ton the equivalent of 164 pounds of sulphate of ammonia. This result is not obtainable in blast furnaces; it is impossible in the manufacture of illuminating coal gas or of coke; but it is realizable to a large extent in the manufacture of heating gas for metallurgical and other uses.

The nascent hydrogen from the water of combustion of the coal is the main element which accomplishes the transformation of the nitrogen into ammonia. Hence, the more water, the more ammonia. If a sufficient outside supply of water is given, all the other conditions being favorable, the total amount of the nitrogen may be secured as ammonia. Practice has demonstrated the correctness of this view. In 1877, Dr. H. Grouven, of Leipzig, discovered that in a large excess of superheated steam, when the necessary conditions of temperature, time, and contact are supplied, combined nitrogen is transformed into ammonia. He applied his discovery to an analytical method of nitrogen determination, which gives concordant results with other accurate methods. Later on, Beilby, Foster, Guéguen and others demonstrated that the coke, which retains a large percentage of nitrogen even at a light red heat, parts with it in the form of

ammonia in the presence of a large excess of steam at an intense heat. Since, in accomplishing this result, the steam is decomposed by carbon, liberating hydrogen, and the carbon is transformed into carbon dioxide and carbon monoxide, it is evident that we have here the elements of a process for producing simultaneously large quantities of ammonia and also heating gas of high calorific value. Between this theoretical reaction, however, and the establishment of an economical manufacturing process, there were many difficulties to overcome. As has been pointed out, the main conditions for the formation of ammonia are eminently favorable to the production of a good heating gas. But high temperature is not compatible with a large excess of steam unless the latter be intensely superheated; and such a temperature cannot be maintained for any considerable time without an outside supply of oxygen or an expensive external heating. Moreover, steam in large excess is liable to produce a gas very high in carbon dioxide, and hence of comparatively little calorific value. Nor should it be forgotten that ammonia, under favorable conditions, is decomposed at a temperature far below that which is required to decompose water and reduce the carbon dioxide into carbon monoxide. The practical operation, therefore, must be so conducted as to maintain the proper heat, make the conditions for the decomposition of ammonia as unfavorable as possible, and, at the same time, produce such a gas as is required in the metallurgy of iron and steel where rapidity of heating and melting, with the lowest percentage of waste, is a prime consideration.

I have found that when high pressure steam is moderately superheated and evenly distributed and diffused in the glowing mass, a limited supply of air, drawn into the generator, is sufficient to maintain the temperature needed to admit continuously from one to one and three-quarters pounds of high pressure steam to the pound of coal, and that this proportion of steam is ample to provoke the necessary reactions which transform into ammonia 50 to 60 per cent. of the total nitrogen of the coal, and still to produce a gas of the following composition:

	Per cent.
Carbon dioxide.....	10.50
Oxygen.....	1.00
Carbon monoxide.....	20.00
Methane and homologous compounds..	4.50
Hydrogen.....	38.00
Nitrogen.....	26.00
	100.00

This gas is rather high in carbon dioxide, but the total of combustible matter is considerable, and the efficiency of the gas in a regenerative furnace for heating iron is very great. It burns with a sharp, white-blue flame, not without luminosity, and heats more rapidly and more economically than the ordinary Siemens gas.

It would seem, at first glance, that the admission of 1 to 1.75 pounds of steam to the pound of coal would have a high cooling effect, hindering the steady production of a gas of the above composition, if the carbon is taken as the only source of heat. Practice shows, however, that such is not the case. There are different ways of accounting for this result. In the first place, independently of the heat furnished by the high pressure superheated steam, many reactions producing heat occur, such as the formation of the ammonia, etc. On the other hand, the gas being exhausted at high speed, the operation takes place under a constant partial vacuum. It is presumable that, under such conditions, the chemical reactions to which we are accustomed are modified, and that we are in the presence of phenomena of physical and thermochemical order, which actuate the distillation of the volatile matter, promote it at a low temperature, and generally facilitate the reactions. Whatever the explanation, the actual result is, that not only there is no cooling effect in the continuous production of the above gas, but that the temperature has a tendency to increase in the zone of combustion. If the steam has been sufficiently superheated and diffused thoroughly in that zone, it is practically all decomposed during the operation; and the reactions proceed without intermission, the liberated nitrogen being transformed in the presence of nascent hydrogen into ammonia, while the resulting fuel gas, as the above analysis shows, is still high in hydrogen.

The danger of dissociation of the ammonia is not as great in practice as has been anticipated. If we remember in what infinitesimal proportion the ammonia is present, diluted, and hence practically protected by the other gases, it is evident that the chance for decomposition, with ordinary care, is very small. And if the product is instantaneously exhausted from the hot atmosphere, carried into the cooler zone immediately above, and led out through green fuel on the top, the ammonia is secured.

With well devised producers and the proper plant, when the art of managing and controlling the heat in the different zones of the fuel bed has been mastered, there is no difficulty in producing regularly, with the proper amount of steam, from each ton of coal, 70 to 80 pounds of sulphate of ammonia; 130,000 to 150,000 cu. ft. of heating gas of high quality; and, in addition, some 15 to 20 gallons of tar, according to the nature of the coal.

The generator must be perfectly accessible, so that it may be easily cleaned, and the coal may be perfectly broken through. The aim should be to keep the fuel like a sponge, but without holes or cavities. The advantages of a good stirring are obvious; it insures the complete diffusion of the steam through the glowing mass, maintains the high temperature in the lower part of the generator, and keeps the top cool, thus tending to secure economy in coal, the minimum of necessary cooling surface in the condensers, and the maximum yield of ammonia. The carbon dioxide should be kept at a minimum. Its formation is a function of temperature; the lower the temperature at which the carbon and air or the carbon and steam come in contact, the more carbon dioxide is formed. It must not be forgotten that the depth of the fuel has a very important bearing on the condition and results.

In order to obtain good heating gas and the largest yield of ammonia and tar, the gas must be well cooled and well scrubbed. If the gas be not cooled, the