they are best seen when Mars reaches its most gibbous form and the angle of the incident light is greatest.

"Le plus souvent les astronomes se bornent à observer Mars vers l'époque de son opposition, c'est-à-dire de sa plus grande proximité de la terre; c'est, pensent-ils, le meilleur moyen de voir bien et de près les 'mers' de Mars. Si ces taches étaient des mers la raisonnablement serait excellent, mais il n'en est pas ainsi. M. Schiaparelli a déjà fait la remarque que les canaux découverts par lui ont été observés non au voisinage de l'opposition mais un mois, deux mois après. Et pourtant la planète est alors bien éloignée de nous. Pour moi, je constate également le même fait; je découvre tous les soirs un nombre de cirques de plus en plus considérable. La raison en est bien simple, du moment que les taches sont des ombres, ou du moins des parties réfléchissant moins la lumière. A l'époque de l'opposition, en effet, les rayons solaires tombent à peu près perpendiculairement sur la surface de la planète; Mars ne possède alors pas de phase, tandis qu'un mois avant ou après, la phase est très accentuée et les ombres deviennent possibles avec les élévations du sol."*

Another attempted explanation was that the channels were doubled in consequence of some play of diffraction. But enough has been said on this head; let us rather turn to the first fruits of last month's work.

At the Lick Observatory the channels were seen, and one of them was considered by three observers to be doubled.

From Peru we learn that Prof. Pickering saw many of the channels observed by Schiaparelli, but all were found to be single. The telegram adds, "not double, as stated by him;" but here is an error. We are near the southern solstice, as in 1877, and they were not seen double at that epoch. But even this is comparatively uninteresting after the revelations as to the effects of the melting snows.

Prof. Pickering discovered two mountain ranges in Mars to the north of the green patch near the planet's south pole. Between these mountain ranges the melted snow has collected before flowing northward. In the equatorial mountain regions snow fell, covering two of the summits, on August 5. On August 7 the snow had melted. "I have seen eleven lakes," the professor writes, "varying in size. These lakes branched out in dark lines connecting them with two large dark areas like seas, but not blue. There has been much local disturbance in the clouds round the planet since the snow melted, as is evident from the dense clouds which were concentrated within one area. These clouds were not white, but yellowish in color, and partly transparent. They now seem to be breaking up, but are still hanging densely on the south side of the mountain range. The northern green spot has been photographed."

Surely we have here the connection between the work of 1862 and 1877. The channels are true water channels; at one time at low channel we may have an unimportant stream like the low Nile; at another an ancient river bed, as it were, is filled to the utmost limit by the inundation. One requires to have seen an Indian river, or better still, the Nile valley, to realize what an inundation may mean, and especially under the conditions which have now been established to exist on Mars. But we may go further. A comparison of Schiaparelli's sketch of 1882 with his map of 1879 helps us considerably, and shows that we must take the effect of clouds over warm water into consideration. Two among the most undoubted and continuous water surfaces which I observed in 1862, which he has named Mare Cimmerium and Sabæus Sinus, were doubled also in 1882, and in my mind there is no doubt whatever that this doubling, at all events, is due to cloud banks lying or, rather, traveling longitudinally along the center of the water surface, precisely as the most magnificent cumuli which I have seen on this planet follow the equatorial current, entering the Caribbean Sea by Tobago. Obviously, by their lightness of shade, the channels are shallow, and they are only noticed in or near the tropics, so that the water must be highly heated before it empties itself into any of the southern seas.

Certainly it must be acknowledged that while the revelations show a remarkable similarity to our own atmosphere, so far as chemical structure and temperature are concerned, for the *onus probandi* lies with those who deny that they are dealing with the various forms of water, it would appear that the extremes of heat and cold are more generally operative in Mars than with us. The problem thus presented to us should prove interesting to the geologist. Was there any period in the earth's past history, or can there be in the future, which more resembles the present Martian conditions? Had we these enormous inundations, chiefly caused by polar snows melting? If not, were we sheltered from them by our more circular orbit and shorter year? Is Mars red because it is muddy? If so, what mud could give it the tinge we know?

J. NORMAN LOCKYER.

LUMINOSITY OF HYDROCARBON FLAMES.†

By VIVIAN B. LEWES, Royal Naval College, Greenwich.

EVER since Sir Humphry Davy, in 1817, advanced his celebrated theory as to the causes of luminosity of certain flames, the subject has commanded a great amount of attention, and the researches of Berzelius, Waldie, Volger, Hilgard, Landolt, Frankland, Stein, Heumann, Kersten, and more recently those of Soret, Birch, Stokes, and Smithells, have all added to our knowledge of the subject, but even now many points remain to be cleared up before we can gain a clear conception of the numerous factors and interactions which go to make up a luminous flame, and it is in hopes of raising a discussion upon some of these points that I venture to bring this paper before you.

Certainly, the two most important landmarks in the history of luminous flames are the original enunciation of the solid particle theory by Davy and Frankland's celebrated attack upon that theory in 1868. The relative values of the views of these two great experimentalists have been so recently discussed that it

would be useless to again go through the mass of evidence which has accumulated during the past twenty-five years, and which seems to point conclusively to the luminous flame of burning hydrocarbons owing their power of emitting light to the presence of incandescent particles of practically pure carbon; while, on the other hand, I believe I am correct in saying that Dr. Frankland is unshaken in his belief that the cause of luminosity is to be found, not in solid particles of carbon, but in the incandescence of heavy hydrocarbon vapors.

In a paper read before the Chemical Society in January last, I described experiments and analyses which showed that the main reaction leading to luminosity in a flame containing hydrocarbons was the conversion in the inner non-luminous zone of the hydrocarbons into acetylene—a change brought about by the baking action of the heat evolved by the combustion in the outer layer of the flame, and in no way dependent upon oxidation, the change being entirely brought about by heat, as can be shown by passing the various gaseous hydrocarbons present in illuminating gases through heated tubes.

If an ordinary flat flame be taken and the gases be carefully withdrawn from the non-luminous zone and analyzed, the ratio of the acetylene formed, to the other unsaturated hydrocarbons, will be found to rapidly increase in their passage up the center of the flame:

Acetylene Formed in the Inner Zone of a Flat Flame from a No. 7 Bray Burner.

Portion of Flame.	Total Unsat. Hydrocarbons.	Acetylene.	Other Unsat. Hydrocarbons.
	Per cent.	Per cent.	Per cent.
½ in. from top of burner.	3.565	0.115	3.450
1¼ in. from burner	2.063	1.303	0.760
1½ " " "	1.393	1.133	0.260
2¼ " " "	trace	trace	—

Showing that by the time the top of the non-luminous portion of the flame is reached over 81 per cent. of the hydrocarbons present are converted into acetylene.

In such a flame luminosity commences just an inch and three-quarters above the burner, and if luminosity is caused by acetylene, it is natural to ask why should it not have commenced at an inch and a quarter—a spot where the acetylene is present in larger quantity than at the higher point. The reason for this is that in order to cause luminosity a temperature must be obtained at which the acetylene is dissociated, and the point at which this takes place marks the commencement of luminosity. If this temperature is not attained, then the acetylene in the presence of oxygen burns away with a non-luminous flame, or, if no oxygen is present, polymerizes into a number of higher hydrocarbons. If, on the other hand, a sufficiently high temperature is reached to cause dissociation, the liberated carbon becomes incandescent chiefly from its own combustion, but partly also from the combustion of the hydrogen liberated at the same time, and luminosity is the result.

The temperature needed to cause the dissociation of acetylene varies with the amount of dilution; the more diluted it is the higher being the temperature necessary to break it up, while the larger the quantity of acetylene the lower the temperature needed to cause its dissociation, and the smaller, therefore, the inner non-luminous zone of the flame.

In the flame from ordinary coal gas there is only from 1.1 to 1.3 per cent. of acetylene found in the inner zone, and in this highly diluted condition it requires a temperature of close upon 1,200° C. to break it up, while in other flames richer in hydrocarbons, and, therefore, richer in acetylene in the inner zone, the temperature required is not so high, for example:

	Flame of Coal Gas.	Flame of Paraffin Lamp.
Percentage of acetylene.	1.133	2.222
Temperature at commencement of luminous zone.	1,267°	1,060°

The fact that unless the requisite temperature is reached the acetylene burns away with non-luminous combustion is, I think, clearly shown by the following experiment:

The flame of burning alcohol contains more than half the quantity of acetylene that a good gas flame contains, and yet the combustion is practically non-luminous. If a dish containing some alcohol be placed under a bell jar, it burns with a flame having slightly luminous edges, and the temperature of the flame in this condition is 1,220° C. If now a glass plate be put over the mouth of the bell jar for a few moments, the mixing of the products of combustion with the air lowers the rate of combustion, and the temperature of the flame falls to 1,050° C., the flame becoming perfectly non-luminous; while, if oxygen be admitted to the bell jar, the combustion is increased and the temperature rapidly rises to 1,510° C., the flame becoming nearly as luminous as a coal gas flame, and depositing carbon on any cold surface held in it.

Again, if a small, luminous gas flame be allowed to play upon the bottom of a platinum dish, so much heat is abstracted from the flame that the temperature falls below the point necessary to break up the acetylene and the flame becomes non-luminous; while, if the flame is allowed to remain in contact with the metal until the dish is red hot, the luminosity returns, and the same effect may be produced by heating the interior of the dish with a blowpipe flame. (This experiment was, I believe, devised by Heumann to show the effect of cooling on luminosity.)

In every flame that I have examined which owes its luminosity to the presence of hydrocarbons, these bodies are converted into acetylene before luminosity commences in the flame, and every gaseous hydrocarbon which can, by heat, be made to deposit carbon, is converted into acetylene before any deposition takes place.

Many of the hydrocarbons present in coal gas are known to give out heat during their decomposition, but probably the most endothermic of these compounds is the acetylene, Thomsen having shown that no less than 55,010 units of heat are absorbed in the formation of 26 grains of acetylene, while only 10,880 disappear in the production of 28 grains of ethylene, and it is this which renders its decomposition by heat or, as shown by Berthelot, even by detonation into carbon and hydrogen so easy.

The fact that acetylene is formed from the gaseous hydrocarbons present in illuminating gas prior to the emission of light does not, however, by itself in any way disprove Dr. Frankland's theory that luminosity is due to very heavy hydrocarbon vapors and not to solid particles of carbon, as the well known tendency of the acetylene to polymerize into higher bodies might be taken as an explanation of the presence of sufficiently dense hydrocarbons in a flame given by say pure ethylene.

In order to determine whether or no the acetylene formed in the earlier stages of the flame renders the flame luminous by liberating carbon during dissociation as required by Davy's theory or by forming heavier hydrocarbons, a long series of experiments were made to ascertain the effect of heat upon the hydrocarbons present in coal gas, and by specially devised apparatus to measure the actual temperature to which the gases were being heated, and to collect and analyze the resulting products. These experiments are still proceeding, but I may state the main results of them as being as follows:

Ethylene passed at the rate of 4 to 5 c. c. per minute through a tube 2 inches in internal diameter undergoes no apparent change until the temperature rises to between 800° and 900° C.; it then breaks down to methane and acetylene; and, simultaneously with the formation of acetylene, heavy vapors appear which can be condensed, and in which benzene and naphthalene are conspicuous, as well as a heavy and highly fluorescent oil of high boiling point. Berthelot found that these substances were formed when acetylene was heated for some time at the temperature at which glass softens, and he also recognized among the products cinnamene, C₁₀H₈, and retene, C₁₅H₁₂, so that there seems very little doubt but that in passing the ethylene through a heated space in which the temperature does not rise above 900° C., methane and acetylene are first formed and the latter at once polymerizes into the heavier hydrocarbons. The amount of acetylene found in the products of the experiment at this temperature rarely exceeds one per cent., as the polymerization occurs almost simultaneously with its formation, but the proportion of ethylene decomposed and the amount of methane found in the products of decomposition point to the initial action of heat at this temperature being:

On increasing the temperature from 900° C. slowly up to 1,000° C. the same action continues, no hydrogen appears in the products of decomposition, and no carbon is deposited, but the formation of oil and solid hydrocarbons is more abundant. Between 1,000° and 1,100° C. a trace of hydrogen appears and a little carbon begins to deposit with the oil, this increasing with rise in temperature up to between 1,300° and 1,400° C., by which time all formation of oil has ceased. Carbon is deposited in larger quantities, and the residual gas consists of hydrogen with a little methane. The temperature at which oil disappears is about 1,200° C., and the proportion of acetylene formed at this temperature is larger than at any of the lower ones.

It is evident, therefore, that if the temperature existing in the luminous portion of the flame exceeds 1,200° C., the luminosity cannot be due to such hydrocarbons as are formed from the acetylene, but that carbon will be present in abundance.

I have made several analyses of the carbon so deposited, and find that the hydrogen in it varies from one to three per cent., and, as there is no fixed ratio, I think there is not the slightest foundation for imagining that it is in combination; indeed, Stein's work upon this point is fairly conclusive, and any one who has attempted to prepare hydrogen-free carbon from sugar, or other similar body, will realize the intense power which freshly liberated carbon has of occluding and holding hydrogen.

Ethane, which is present in illuminating gas in larger proportion than is generally supposed, breaks up even below 800° C. into ethylene and hydrogen—

and the ethylene behaves as before on increase of temperature. Methane, which is only present in very large quantities in the original gas, but is also produced during the decomposition of the ethylene, is apparently unaffected by heat until a temperature of 1,000° C. is reached, when hydrogen and unsaturated hydrocarbons begin to appear in small traces. Acetylene being the chief of these, this action continues and increases, so that at about 1,500° C. considerable quantities of acetylene are formed, which at once break down to hydrogen and carbon. With methane, as with ethylene, the first trace of acetylene found in the products is also accompanied by the formation of oils and heavy condensable vapors. Methane is not so easily converted into acetylene as the other hydrocarbons, and requires a higher temperature to bring about the change; but the fact that it does so at high temperatures fully explains the facts first observed by Dr. Percy Frankland and Mr. Lewis Thompson, that although methane when burnt by itself has but a very feeble power of illumination, yet when used as a diluent of heavier hydrocarbons it greatly increases the light-emitting power of the flame.

In order to apply the knowledge these experiments give of the changes taking place in the hydrocarbons present in coal gas during their flow through the heated channel in the interior of the flame, it is necessary to map out the temperatures existing in a luminous flame, and the flat flame from a Bray burner (No. 7) lends itself conveniently to this purpose.

Using the Le Chatelier thermo-couple described by Dr. Roberts-Austen at the last meeting of the British Association, and making only one short twist of the wires to give contact, and then coating them with hard glass, it is possible for nearly a minute to get the temperature in the portion of the flame in which the short twist is plunged, and if thin wires are used the loss by

* "Note sur la Découverte du Système Géologique Eruptif de la planète Mars." Par Fr. Mayeur Lamy, O.S.B. Auton. (Dejussien, 1884.)

† Read before the British Association, Edinburgh meeting, 1892, chemical section.

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 outer skin 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