in which w , b , l , w' , b' , l' , are the weights, breadths, and spans for two cases; $n = 2.25$ was the mean result of solutions of the above equations.

Proceedings Insti. Civil Engineers, April 10, 1862.

MECHANICS, PHYSICS, AND CHEMISTRY.

On the Igniting Point of Coal Gas. By Dr. E. FRANKLAND, F.R.S.

From the Journal of Gas Lighting, Water Supply, and Sanitary Improvement, No. 250.

The temperature at which coal gas will ignite under ordinary or extraordinary conditions, is a circumstance of considerable importance, both to manufacturers and consumers of gas; nevertheless, the recent explosion in Holborn, and the difference of opinion which evidently prevails, even amongst those who are intimately acquainted with the properties of coal gas, prove that the subject has not hitherto received that attention which it obviously merits. Under these circumstances, the following experiments, and the conclusions drawn from them, although they are far from exhausting the subject, may not perhaps be altogether unacceptable as a contribution to this part of the history of coal gas.

The heterogeneous mixture of gases and vapors known as coal gas, may, for our present purpose, be assumed to consist of:—

Olefiant gas and other luminiferous hydrocarbons.

Light carburetted hydrogen, or fire-damp.

Hydrogen.

Carbonic oxide.

Bisulphide of carbon.

Now, as these constituents can, to some extent, become separated from each other, under certain circumstances, it is desirable, at the outset of the inquiry, to examine separately their respective igniting points.

1. Olefiant gas, which may be taken also as the type of the remaining luminiferous hydrocarbons, could not be inflamed by a hot iron, unless the latter were heated until it appeared of a cherry-red color in the daylight of a tolerably well-lighted room.

2. The igniting point of light carburetted hydrogen was carefully determined by Davy, to whose observations I have not a word to add. He says that "light carburetted hydrogen can be inflamed by *white hot sparkling iron*, but not by iron at a red heat; it is, therefore, much less inflammable than hydrogen or carbonic oxide, and less so than olefiant gas." Bischof says that it cannot be inflamed by burning tinder, even though the tinder be strongly blown upon.

3. Hydrogen inflamed at a lower temperature than olefiant gas, but it could not be ignited by a rod of iron, unless the latter were heated to a temperature considerably beyond visible redness in a tolerably well-lighted room.

4. Carbonic oxide inflamed at a temperature somewhat greater than

that at which hydrogen ignited, but lower than that necessary for the inflammation of olefiant gas.

5. Bisulphide of carbon vapor ignited at 300° Fahr.

In some experiments recently made in connexion with the gas explosion in Wood Street, I had occasion to observe that when coal gas is allowed to mix with air contained in a space, partly enclosed, but still communicating freely with the atmosphere, such as the open gas main in Holborn, for instance, there occurred an approximate separation of the lighter from the heavier constituents of the gas; thus samples of the explosive mixture taken from such a space were found on analysis to contain olefiant gas, luminiferous hydrocarbons, carbonic oxide, and bisulphide of carbon, with but a small per centage of light carburetted hydrogen, and mere traces of hydrogen, although the two latter gases constitute, as is well known, the chief bulk of coal gas. These gases must, therefore, have rapidly made their way out of the partially-enclosed space into the atmosphere. This behaviour of the different constituents of coal gas, when the latter is slowly admitted into one end of an open main containing atmospheric air, may not inaptly be compared to that of a number of birds of different powers of flight, entering at one end of the pipe, and making the best of their way towards the opposite extremity. At every moment from the entrance of the birds, the per centage of those of swift flight would diminish near the entrance end of the pipe, whilst that of the birds of slower velocity would obviously increase in the same ratio.

The Master of the Mint has proved that the rapidity with which gases diffuse into each other, or into a vacuum, is inversely proportional to the square roots of their specific gravities; and, although there are some circumstances in the case of the open gas main, or partially-enclosed space, which would somewhat interfere with this ratio, yet, for all practical purposes, Mr. Graham's law may be assumed to express correctly the different velocities with which the constituents of coal gas would hasten to escape from the space in question.

These velocities of diffusion are as follow:—

Bisulphide of carbon,	.	.	.	1.00
Olefiant gas,	.	.	.	1.66
Carbonic oxide,	.	.	.	1.66
Light carburetted hydrogen,	.	.	.	2.19
Hydrogen,	.	.	.	6.23

All other luminiferous hydrocarbons existing in coal gas must have a diffusion velocity lower than that of olefiant gas.

Thus the effect of diffusion of coal gas in an open horizontal pipe, or other similar partially-enclosed space, would be to form an explosive mixture, containing chiefly hydrogen as the combustible gas, at or near the open extremity of the pipe; whilst the explosive mixture, formed near the end of the pipe where the gas entered, would contain chiefly carbonic oxide, olefiant gas, and bisulphide of carbon.

It is obvious, from experiment No. 3, that the explosive mixture, formed near the mouth of the tube, would ignite at a somewhat lower temperature than that required for the ignition of an explosive mixture containing all the constituents of coal gas. Still, even this more inflammable mixture could not be ignited below a red heat distinctly visible in the daylight of a room. It might, however, be expected that the explosive mixture, formed at the opposite extremity of the tube, would be capable of ignition at a still lower temperature, owing to the continued increase in the proportion of the highly inflammable but sluggish bisulphide of carbon, which could, doubtless, under favorable circumstances, increase to at least ten times the amount originally contained in the coal gas. In order to ascertain the effect of the presence of a considerable per centage of bisulphide of carbon vapor upon the inflammability of the constituents of coal gas, and especially of carbonic oxide and olefiant gas, the following experiments were made:—

6. Carbonic oxide was mixed with about 3 per cent. of the vapor of bisulphide of carbon, and was then allowed to issue from a jet into the air. The jet of gas readily ignited on the approach of a glass tube containing oil heated to 410° Fahr., the igniting point of the gas being probably not higher than 350° Fahr.

7. Hydrogen, containing the same amount of bisulphide of carbon vapor, ignited by contact with a tube containing oil at 420° Fahr.

Here, then, was a phenomenon which would seem to indicate the alarming possibility of the ignition, at a comparatively very moderate heat, of explosive mixtures of coal gas and air; fortunately, the next experiments entirely allay any apprehensions on this score.

8. Olefiant gas, impregnated with 3 per cent. of the vapor of bisulphide of carbon, did not inflame at a perceptibly lower temperature than when free from the admixture of the sulphur compound.

9. To the highly-inflammable mixture of carbonic oxide and vapor of bisulphide of carbon, used in experiment No. 6, a minute trace (not 0.1 per cent.) of olefiant gas was added; instantly, the igniting point of the mixture was raised to that of pure carbonic oxide.

10. A similar experiment with the hydrogen mixture (No. 7), gave a corresponding result.

Thus, the extraordinary inflammability which is imparted to carbonic oxide and hydrogen by the vapor of bisulphide of carbon, is entirely removed by mere traces of olefiant gas; and it is probable that the other luminiferous hydro-carbons contained in coal gas would produce the same effect. In order to complete this part of the inquiry, it now only remained to extend these experiments to coal gas itself.

11. Coal gas could not, even under the most favorable circumstances, be ignited at a temperature perceptibly below that described in experiment No. 4, as necessary for the inflammation of carbonic oxide.

12. When coal gas was mixed with 3 per cent. of bisulphide of carbon vapor, its igniting point was not lowered in the slightest degree.

Having thus proved that any amount of diffusion can have but a very slight effect upon the inflammability of explosive mixtures of coal gas and air, the following experiments were made to decide the disputed point, whether coal gas can be inflamed by sparks:—

13. Hydrogen was readily inflamed by sparks struck from flint and steel.

14. Carbonic oxide was also readily ignited in a similar way.

15. The mixture of coal gas and air, issuing from a wire-gauze burner, was repeatedly, and easily, inflamed by the sparks struck from flint and steel.

These results are quite in conformity with the experience of gas-engineers and managers, several letters from whom are now before me, describing the ignition of gas from the sparks elicited by the contact of a workman's pickaxe with stones, the chipping of a main, &c. The notion that coal gas will not inflame under these circumstances has, doubtless, arisen from the impossibility of so igniting the gas of coal mines; but the combustible gas existing in British coal mines has been proved, by very numerous analyses, to be light carburetted hydrogen only—no trace of hydrogen, carbonic oxide, or olefiant gas being ever present in it. Now, the igniting point of light carburetted hydrogen, as has already been explained, is very much higher than that of the other combustible gases present in coal gas, and hence, whilst the mine may be safely lighted by the "steel mill," the use of such an instrument in an explosive mixture of coal gas, would infallibly cause ignition. A word of warning as to the use of the safety-lamp in gas-works may perhaps not be here out of place. Even in the difficultly inflammable fire-damp mixture of coal mines, the Davy lamp was known by its inventor to be unsafe in certain conditions,—as when placed in a strong draft, or rapidly swung to and fro. Any degree of insecurity thus attaching to the safety-lamp in mines, is increased tenfold when it is used in explosive mixtures of coal gas, and hence it is highly desirable that the gauze of such lamps should be finer than that used in the miner's lamp, and also that the workmen should be stringently prohibited from placing the lamps in a draft of explosive gas, or swinging them to and fro, since the neglect of these precautions may easily cause disastrous explosions.

In conclusion, the results arrived at may be thus shortly summed up:—

1. Coal gas cannot, even under the most favorable circumstances, be inflamed at a temperature below that necessary to render iron very perceptibly red hot by daylight in a well-lighted room. But this temperature is considerably below a red heat visible in the open air on a dull day.

2. This high igniting point of coal gas under all circumstances, is due in a great measure to the presence of olefiant gas and luminiferous hydrocarbons.

3. The igniting point of explosive mixtures of the gas of coal mines is far higher than that of similar mixtures of coal gas; consequently, degrees of heat, which are perfectly safe in coal mines, may ignite

coal gas; hence, also, the safety-lamp is much less safe in coal gas than in fire-damp.

4. Explosive mixtures of coal gas and air may be inflamed by sparks struck from metal or stone. Thus, an explosion may arise from the blow of the tool of a workman against iron or stone, from the tramp of a horse upon pavement, &c.

5. Explosive mixtures of coal gas may also be ignited by a body of a comparatively low temperature, through the medium of a second body, whose igniting point is lower than that of coal gas. Thus sulphur, or substances containing sulphur, may be inflamed far below visible redness; and the contact of iron below a red heat with very inflammable substances, such as cotton waste, may give rise to flame, which will then, of course, ignite the gaseous mixture.

The Waste Products of Gas Works.

From the Journal of Gas Lighting, &c., No. 250.

Dr. Lyon Playfair is delivering a short course of lectures at the Royal Institution, on the progress of some of the chemical arts since 1851, and in his first two lectures, on the 8th and 15th inst., his subject was "The Distillation of Coal." He selected that subject, he observed, not because there had been any marked improvement in the manufacture of gas, but on account of the new applications of the products of gas works, which had given great value to what was formerly considered to be valueless. In the first lecture, he described the various processes of gas making, and explained the principle on which the illuminating power of gas depends. In endeavoring to illustrate the effect of enriching pure hydrogen gas by passing it through naphtha, the glass vessel in which the fluid was contained exploded when he applied a light to it, and fragments of glass were scattered in all directions, and dense brown fumes filled the lecture-room, and drove many of the ladies away. He exhibited a large and beautiful mass of paraffin, and a bundle of paraffin candles that had been made from coal-tar, and contrasted the present state of the manufacture and the use of that article with its condition in 1851, for in the Exhibition of that year, a single paraffin candle only was exhibited as a great curiosity, which had been produced from peat; whilst in the Exhibition now open, there are abundant specimens of the paraffine wax and candles made from coal-tar, the production of that article having become an important branch of manufacture.

In the second lecture, the ammoniacal products, and the dyes produced from coal-tar, were noticed. He stated that 4000 tons of the muriate, 5000 tons of the sulphate, and 2000 tons of the carbonate of ammonia are annually produced from gas liquor; and he no doubt surprised and somewhat disgusted the lady portion of his audience by informing them that their smelling bottles are filled from the refuse of gas works, and the sweepings of streets. He exhibited the process of extracting oil and naphtha from coal, and proceeded to de-