

Mechanics, Physics, and Chemistry.

ON THE SOURCE OF LIGHT IN LUMINOUS FLAMES.

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THE most prolific source of error amongst mankind is the unquestioning acceptance of authoritative opinion. However much we may pride ourselves upon the sifting of the explanations of things by our own enlightened judgments, it cannot be denied that the *ipse dixit* mode of settlement is still wonderfully frequent amongst us. Not only is this the case with the public in general, but even the cultivators of science are not entirely innocent of the same weakness.

The essential difference between a fact and a theory is not always appreciated with sufficient vividness. The statement that "16 parts by weight of oxygen unite with 2 parts of hydrogen to form water," is considered by many, for instance, as perfectly synonymous with the assertion that "1 atom of oxygen unites with 2 atoms of hydrogen to form water."

The existence of an imponderable ethereal medium filling all space is often regarded as equally certain with the presence of a gaseous envelope surrounding our globe.

The atomic theory and the hypothesis of an ethereal medium are, at present, absolutely necessary, the one to the progress of chemistry, the other to the further development of physics; but neither this circumstance nor the splendid discoveries made by their aid can establish their truth. A mathematician starting from false data is sure to arrive at a false result; but it is far otherwise with theory, for false theories can, and constantly do, conduct to true facts. Thus Columbus's counterpoise theory of the earth led to the discovery of America, although that theory was, nevertheless, essentially false.

The most sober worker in science cannot progress without the assistance of theory to co-ordinate his facts, and to lead him on to further research. It is here that even a false theory is invaluable, and it is only when the theory continues to be held after it has become opposed to facts, that it exercises a prejudicial influence

upon the progress of science. Then it hinders rather than expedites the advance of the experimenter, and ought to be at once abandoned.

In pursuing the investigation forming the subject of this discourse, the speaker had been compelled thus to abandon a theory of the source of light in luminous flames, which he, in common with others, had derived from Davy's classical researches on flame.

Our text-books answer the question, *What is the source of light in a luminous gas or candle flame?* in the most positive and unanimous manner.

Selecting from some of the most celebrated, the following quotations may be made:—

“All our artificial lights depend upon the ignition of solid matter, in the intense heat developed by the chemical changes attendant on combustion.”—*W. A. Miller.*

“Whenever hydrocarbons are imperfectly burnt, there is a deposition of carbon, and this temporary deposition of carbon is an *essential* condition for the production of the white light required in an ordinary flame.”—*Williamson.*

“The illuminating power of the gas flame is, therefore, due to these *carbon particles*, which are afterwards burned nearer the border of the flame.”—*Balfour Stewart.*

“The brightness or illuminating power of flame depends not only on the degree of heat, but likewise on the presence or absence of solid particles which may act as radiant points. A flame containing no such particles emits but a feeble light, even if its temperature is the highest possible.”—*Watts.*

The speaker then proceeded to investigate a number of different flames: he showed that there are many flames possessing a high degree of luminosity, which cannot possibly contain solid particles. Thus the flame of metallic arsenic, burning in oxygen, emits a remarkably intense white light; and as metallic arsenic volatilizes at 180° C., and its product of combustion, arsenious anhydride, at 218° C., whilst the temperature of incandescence in solids is at least 500° C., it is obviously impossible here to assume the presence of ignited solid particles in the flame. Again, if carbonic disulphide vapor be made to burn in oxygen, or oxygen in carbonic disulphide vapor, an almost insupportably brilliant light is the result; now, fuliginous matter is never present in any part of this flame, and the boiling point of sulphur (440° C.) is below the

temperature of incandescence, so that the assumption of solid particles in the flame is here also inadmissible. If the last experiment be varied by the substitution of nitric oxide gas for oxygen, the result is still the same; and the dazzling light produced by the combustion of these compounds is also so rich in the refrangible rays, that it has been employed in taking instantaneous photographs, and for exhibiting the phenomena of fluorescence. Lastly, amongst the chemical reactions celebrated for the production of dazzling light, there are few which surpass the active combustion of phosphorus in oxygen. Now, phosphoric anhydride, the product of this combustion, is volatile at a red heat,* and it is, therefore, manifestly impossible that this substance should exist in the solid form at the temperature of the phosphorus flame, which far transcends the melting point of platinum.

For these reasons, and for others which the speaker had stated in a course of lectures on "Coal Gas," delivered in March, 1867, and printed in the *Journal of Gas Lighting*, he considered that incandescent particles of carbon are not the source of light in gas and candle flames, but that the luminosity of these flames is due to radiations from dense but transparent hydrocarbon vapors. As a further generalization from the above-mentioned experiments, he was led to the conclusion that dense gases and vapors become luminous at much lower temperatures than aeriform fluids of comparatively low specific gravity; and that this result is, to a great extent, if not altogether, independent of the nature of the gas or vapor, inasmuch as he found that gases of low density, which are not luminous at a given temperature when burnt under common atmospheric pressure, become so when they are simultaneously compressed. Thus, mixtures of hydrogen and carbonic oxide with oxygen emit but little light when they are burnt or exploded in free air, but exhibit intense luminosity when exploded in closed glass vessels, so as to prevent their expansion at the moment of combustion.

In a communication just made to the Royal Society, the speaker

* Davy mentions this fact in connection with his view of the source of luminosity in flames, and endeavors to explain the (to him) anomalous phenomenon. He says: "Since this paper has been written, I have found that phosphoric acid volatilizes slowly at a strong red heat, but under a moderate pressure it bears a white heat; and in a flame so intense as that of phosphorus, the elastic force must produce the effect of compression."—*Davy's Works*, vol. vi., p. 48.

had described the extension of these experiments to the combustion of jets of hydrogen and carbonic oxide in oxygen under a pressure gradually increasing to twenty atmospheres. These experiments, which were conducted in the laboratory of the Royal Institution, were made in a strong wrought-iron vessel furnished with a thick glass plate of sufficient size to permit of the optical examination of the flame. The appearance of a jet of hydrogen burning in oxygen under the ordinary atmospheric pressure was exhibited. On increasing the pressure to two atmospheres, the previously feeble luminosity was shown to be very markedly augmented, whilst at ten atmospheres' pressure, the light emitted by a jet about one inch long was amply sufficient to enable the observer to read a newspaper at a distance of two feet from the flame, and this without any reflecting surface behind the flame. Examined by the spectroscope, *the spectrum of this flame is bright and perfectly continuous from red to violet.*

With an higher initial luminosity, the flame of carbonic oxide in oxygen becomes much more luminous at a pressure of ten atmospheres, than a flame of hydrogen of the same size and burning under the same pressure. The spectrum of carbonic oxide burning in oxygen under a pressure of fourteen atmospheres is very brilliant and perfectly continuous.

If it be true that dense gases emit more light than rare ones when ignited, the passage of the electric spark through different gases ought to produce an amount of light varying with the density of the gas; and the speaker showed that electric sparks passed as nearly as possible, under similar conditions, through hydrogen, oxygen, chlorine and sulphurous anhydride, emit light, the intensity of which is very slight in the case of hydrogen, considerable in that of oxygen, and very great in the case of chlorine and sulphurous anhydride. On passing a stream of induction sparks through the gas standing over liquefied sulphurous anhydride in a strong tube, at the ordinary temperature, when a pressure of about three atmospheres was exerted by the gas, a very brilliant light was obtained. A stream of induction sparks was passed through air confined in a glass tube connected with a condensing syringe, and the pressure of the air being then augmented to two or three atmospheres, a very marked increase in the luminosity of the sparks was observed, whilst on allowing the condensed air to escape, the same phenomena were observed in the reverse order.

Way's mercurial light was also exhibited as an instance of intense light by the ignition of the heavy vapor of mercury.

The gases and vapors just mentioned have the following relative densities :—

Hydrogen.....	1
Air.....	14.5
Oxygen.....	16
Sulphurous anhydride.....	32
Chlorine.....	35.5
Mercury.....	100
Phosphoric anhydride.....	71 or 142

The feeble light emitted by phosphorus when burning in chlorine seems, at first sight, to be an exception to the law just indicated, for the density of the product of combustion (phosphorous trichloride) 68.7 would lead us to anticipate the evolution of considerable light. But it must be borne in mind that the luminosity of a flame depends also upon its temperature, and it can be shown that the temperature in this case is probably greatly inferior to that produced by the combustion of phosphorous in oxygen. We have not all the necessary *data* for calculating the temperature of these flames, but, according to Andrews, phosphorus burnt in oxygen gives 5747 heat units, which, divided by the weight of the product from one grain of phosphorus, gives 2500 units. When phosphorus burns in chlorine, it gives only (according to the same authority) 2085 heat units, which, divided as before by the weight of the product, gives 470 units. It is, therefore, evident that the temperature in the latter case must be greatly below that produced in the former, unless the specific heat of phosphoric anhydride be enormously higher than that of phosphorous trichloride. The speaker had, in fact, found that if the temperature of the flame of phosphorus, burning in chlorine, be raised about 500° C. by previously heating both elements to that extent, the flame emitted a brilliant white light.

To return to ordinary luminous flames, the argument of the *necessity* of solid particles to explain their luminosity obviously falls to the ground; and a closer examination into the evidence of the existence of these particles reveals its extreme weakness. Soot from a gas-flame is not elementary carbon, it always contains hydrogen. The perfect transparency of the luminous portion of flame also tends to negative the idea of the presence in it of solid particles. The continuous spectrum of gas and candle-flames does not require,

as is commonly supposed, the assumption of solid particles. The spectra of the flames of carbonic oxide in air, of carbonic disulphide, arsenic, and phosphorus in oxygen, are continuous, and so, as we have seen, is that of hydrogen burning in that of oxygen under a pressure of ten atmospheres. It is to the behavior of hydrocarbons under the influence of heat that we must look for the source of luminosity in a gas-flame. These gradually lose hydrogen, whilst their carbon atoms coalesce to form compounds of greater complexity, and, consequently, of greater vapor density. Thus marsh-gas (C_2H_4) becomes acetylene (C_2H_2), and the density increases from 8 to 13. Again, olefiant gas (C_2H_4) forms naphthaline (C_{10}H_8), when the vapor density augments from 14 to 64. These are some of the dense hydrocarbons which are known to exist in a gas-flame; but there are, doubtless, others still more dense; pitch, for instance, must consist of the condensed vapors of such heavy hydrocarbons. for it distills over from the retorts in the process of gas-making, Candle-flames are similarly constituted. The direct dependence of the luminosity of gas and candle-flames upon atmospheric pressure, also strongly confirms the view that the light of these flames is due to incandescent dense vapors.

This inquiry cannot be confined to terrestrial objects. Science seeks alike for law in the meanest and grandest objects of creation. From questioning a candle she addresses herself to suns, stars, nebulae, and comets; the same considerations which have just been applied to gas and candle-flames are equally pertinent to these great cosmical sources of light.—*Proceedings of the Royal Institution.*

A NEW ARRANGEMENT OF THE HOLTZ MACHINE.

BY PROF. H. L. SMITH.

IN the ordinary mode of excitation of the Holtz Machine, the knobs of the dischargers are placed in contact, and afterwards separated; the excitation cannot be produced without contact. It follows that, when the balls are separated beyond the striking distance, all action will suddenly cease, and to renew it the balls must again be brought together; and, frequently, in addition to this, a new excitation of the sectors will be required.

A large class of electrical experiments require, virtually, this