

LIV.—*On the Temperature of Certain Flames.*

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HAVING, for some years past, given much attention to flames and the nature of the spectra they emit, I have endeavoured to ascertain, as far as practicable, the temperatures they were capable of attaining. Unfortunately no thermometer or pyrometer, even of the nature of H. Le Chatelier's thermoelectric couple, is suitable, because the mass of the material to be heated is too large, and in the use of the latter instrument its destruction would be involved in the measurements attempted.\* It is impossible to measure with accuracy the *maximum* temperature of any part of a flame of small dimensions, because if a body is placed within the flame it must necessarily reduce its temperature.

I have elsewhere mentioned the fact that a candle flame is hot enough to melt platinum, if the material to be melted be only small enough to be surrounded by the heated gases, and not large enough to conduct the heat away. ("Oxy-hydrogen Blow-pipe Spectra." Part I. *Phil. Trans.*, 185, 161—212.)

From recent publications and discussions I imagine there must be some misconceptions prevalent as to the temperature of flames.

In this connection, I may quote Sir Humphrey Davy, "The real temperature of visible flame is perhaps as high as any we are acquainted with. Mr. Tennant was in the habit of showing an experiment, which demonstrates the intensity of its heat. He used to fuse a filament of platinum in the flame of a common candle; and it is proved by many facts that a stream of air may be made to render a metallic body white hot, yet not itself be luminous." (*Phil. Trans.*, 1816, 117.) "Flame is gaseous matter heated so highly as to be luminous, and to a degree of temperature beyond the white heat of solid bodies, as is shown by the circumstance, that air not lumi-

\* Professor Vivian Lewes has used this form of pyrometer with wires of very small dimensions for measuring the temperature of flames.

nous will communicate this degree of heat. This is proved by the simple experiment of holding a fine wire of platinum about  $1/20$ th of an inch from the exterior of the middle of the flame of a spirit lamp, and concealing the flame by an opaque body, the wire will become white hot in a space where there is not visible light." (*Phil. Trans.*, 1817, 68.)

*Evidence of the High Temperature of a Candle Flame.*—That combustion in a candle flame is productive of a very high temperature is capable of proof in various ways.

1st. Pure gold leaf melts with extreme ease in any part of a candle flame where there is complete combustion, from the point where the wick curls over, or just under the tip of the curl, up to the apex of the flame. The highest temperature is about halfway up near the zone of greatest luminosity, and either within or near to the mantle. Hence the temperature at the lowest computation cannot be less than  $1045^{\circ}$  C. at these positions. This experiment is not open to the objection that the gold combines with carbon contained in the flame, and that by such change its melting point is lowered, for this is not the fact.

2nd. Faraday has described how he melted platinum wires  $1/3000$ th of an inch in diameter in a candle flame. (*Lectures on the Chemistry of a Candle*, 195. C. Griffin and Co., 1865.) I have myself melted fine wires of platinum in a candle flame, and the melting point of this element cannot be less than  $1775^{\circ}$  C. (Violle).

It has been remarked that a possible fallacy may underlie the deductions drawn from the behaviour of a platinum wire in a flame containing free carbon or carbonic oxide, on account of the specific chemical action which these substances may exert on the metal. (*Proc. Chem. Soc.*, 16th January, 1896, 5.)

While fully recognising the propriety of drawing attention to this matter, it is right to say that I can find no evidence of the melting point of platinum being lowered by the action of carbon, and according to my experience it is not materially altered.

3rd. The most striking evidence of the very high temperature even of a candle flame is obtained by a careful examination of the spectra which can be observed in it. The line spectrum of sodium which is caused by the dissociation of its oxide may usually be seen, and the spectrum of calcium oxide may be obtained by putting a trace of lime on the wick. But by far the most convincing proof of the very high temperature of the flame is the well known fact that the spectrum of carbon is always visible in the mantle. The two groups of bands in the yellowish-green, with wave-lengths about 5627 to 5372, and 5170 to 5086, are particularly brilliant, and also the group in the blue, wave-length from 4743 to 4688. Any flame

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showing these bands, which belong to the vapour of carbon, and which can show the radiations characteristic of the vapour of calcium oxide, must be at a temperature approaching that of the oxy-hydrogen flame.

*Proof that the Melting Point of Platinum is not materially Reduced by Carbon in the Flame.*—In order to ascertain whether heating a platinum wire in a flame containing free carbon gives rise to the formation of a compound of platinum and carbon which melts at a lower temperature than pure platinum, the following experiments were made.

A length of about 17 inches of platinum wire was fixed to a support by means of a screw, the end of which nipped the wire; the opposite end was allowed to lie on a triangular file as a support, and through the wire a current of electricity was passed. The wire was then very gently drawn along the flat, horizontal surface of the triangular file until it was obvious that the metal was near its melting point. Then with increased caution the wire was shortened, but without exercising the slightest tension, until it grew hotter, and finally gave way by fusion.

The portion of the white-hot wire dropped immediately over the sharp edge of the file and was then squeezed down upon it to show exactly where contact was made, and the distance from this point to that end of the wire which had not been heated by the current was carefully measured. By deducting its length from the total length of the wire, the exact quantity which had been heated to melting point was ascertained. Some of the same wire was then heated for 10 or 15 minutes in a broad bat's-wing burner until it had lost its brightness. From time to time a coating of carbon could be seen upon it. This wire was then tried exactly in the same way; the results obtained being as follows.

*Length of Wire heated to its Melting Point.*

	I.	II.	III.
Pure platinum . . . . .	$10\frac{1}{16}$ ths	$10\frac{2}{16}$ ths	10 inches.
Carbonised platinum..	$10\frac{9}{16}$ ths	$10\frac{4}{16}$ ths	10 „

It will thus appear that the melting point of the metal had not been altered.

That the current from the 15-storage cells decreased by use in the interval between the first and second pairs of experiments accounts for the reduced length of wire shown to have been heated, but inequalities in the wire and also increased accuracy in performing the experiment may also have had effect.

Thus the doubt that was cast upon the accuracy of Professor

Smithell's statement of the high temperature of the mantle of the Bunsen flame may be said to be dissipated.

The melting of platinum wires in a candle flame cannot be carried out with any ordinary wire. That which I used\* was drawn by Wollaston's method—a core of platinum inside a tube of silver. The silver was dissolved away from several short lengths of wire by digesting it in strong nitric acid, in some instances, for a period of a week, until no more silver was removed, and the wires were then washed with distilled water until nothing further could be removed from them. They were invisible to the unaided eye, except when they were struck by a ray of sunlight. It is difficult to introduce more than very short lengths of wire into the flame, because the up-rush of heated gas or vapour carries the wire away with it. But, if held by two ends, the wire, though invisible, may be passed into the flame when it instantly melts.

I have made some experiments on other flames, all of which have a temperature as high as that of a candle. Platinum wire 1/1000th of an inch thick melts in any part of a hydrogen flame 1 inch in height; it melts in the inner cone of a cyanogen flame with extreme ease, also in the flame of carbon monoxide, when only 1 inch in height, if introduced into the inner cone of the flame, and with great ease if placed at the tip of the cone. It must be recollected, however, that a carbon monoxide flame 1 inch in height is of much larger volume than a candle flame of this height, because the gas does not ignite if allowed to flow under pressure from a narrow orifice. In this case the orifice was a platinum tube of 1/8th of an inch internal diameter. The temperatures thus recorded cannot have been lower than 1775° (Violle).

The latter experiment goes to confirm my calculation of the temperature of the Bessemer flame, based on the comparison of its spectrum with the spectra produced by the oxyhydrogen flame, and from the fact that the flame from a converter is the result of the combustion of carbon monoxide mixed with about twice its volume of nitrogen, the gaseous mixture burning in air with an initial temperature of about 1500° (*Phil. Trans.*, 185, 1041).

\* Obtained from Messrs. Johnson and Matthey.