

SULPHONAL.

THE Brussels Medical Journal, in an article by Dr. L. Stenon, gives the following *resumé* of the results published during 1888 by seventeen medical authors who have written on this new therapeutic agent: Sulphonal was discovered by Baumann. It is diethylsulphonedimethylmethane. *Character*.—Thick crystals, melting at 130 to 131° C., soluble in 15 parts of boiling water, in 133 parts of ether, and 65 parts of alcohol at 15°; rather soluble in benzole and chloroform, nearly insoluble in cold water. It is without odor and taste, sometimes slightly bitter. *Experiments on animals*.—Given at the dose of 2 grammes (30 grains English) to a dog, sulphonal produces in 30 to 45 minutes disordered movements and then sleep. At the dose of 78 milligrammes (a milligramme is one sixty-fifth grain English) for each kilogramme (2 lb.) weight of the animal, sulphonal produced in two guinea pigs a fall of temperature equal to 1.4° C. (2½° Fahr.) No action on the movements of the heart or on those of respiration. No influence on the digestive functions. *Effects on healthy men*.—2 to 3 grammes prolong (exaggerate) normal sleep. *Effects on patients*.—In the most varied pathological cases (neuroses, mental disease, senility, cerebral lesions, acute diseases, cardiac affections, etc.), sulphonal at the dose of 2 to 3 grammes (the gramme is about 15 grains English) produces in from half an hour to two or three hours a calm and deep sleep which lasts from five to eight hours. Next day no important after effects are observed. The patient on awakening experiences a feeling of well being. With agitated persons (general paralysis, morphinomania) the effects are less satisfactory. The day after high doses the head is affected, there is fatigue and vertigo. In one case sulphonal produced an exanthema similar to variola. *Indications*.—In nervous insomnia, especially in melancholia and morphinomania. *Counter-indications*.—The action is *nil* or next to *nil* in cases of great agitation, pain, cough, and disordered respiration. The use of sulphonal has given rise to accidents (repeated attacks of angina pectoris) in a man who was suffering from atherosclerosis. *Mode of administration and doses*.—1 gramme (15 grains) will not with certainty produce any effect. 2 grammes (30 grains) are almost always effective. Some practitioners give 3 or 4 grammes, or even 5 grammes. The dose of 25 to 30 centigrammes (4 to 5 grains) is sufficient for children. The patient does not get accustomed to the drug. It is best given as a powder and the whole dose at once, followed by some warm drink, preferably by hot soup (bouillon), which causes it to dissolve.

ON FLAME.*

By F. J. ROWAN.

THE subject of flame possesses considerable interest from a technical point of view, because the questions connected with its nature and propagation enter into our understanding of several problems which are of first-rate importance to practical applications of science.

The nature of flame and the temperature which results from its existence bear directly upon our application of fuel and on the intensity of the heat which we produce by combustion. The velocity of ignition is a matter which in several ways is closely connected with the safe working of collieries; and recent research has shown us that the principles of gas engine practice embrace considerations alike of the nature, temperature, and propagation of flame.

In the following remarks the author aims merely at setting forth some of the general principles of the subject, without making any specific application of them to the important problems indicated.

Nature of Flame.—What is flame? Dr. Mills has remarked that a flame may be regarded as volatile matter undergoing chemical change at a visibly red heat; and Dr. Percy, with more minuteness, says:

"Ordinary flame is gas or vapor of which the surface, in contact with atmospheric air, is burning with the emission of light."

These definitions leave little to be desired, as they properly direct attention to *visibility* rather than to temperature, and to the fact that the presence of combustible *gas* or *vapor* is a necessary condition to the existence of flame. We may have a solid, such as iron, magnesium, or carbon, burning in oxygen or air, at a high temperature, with brilliant incandescence, or glowing, but without flame, while, on the other hand, the flame of boric methide shows that flame may exist without a high temperature.

Flames are usually regarded as simple or compound, according to the number of products which result from them. Those which are ordinarily used in the arts and manufactures are compound flames.

From the foregoing definition of flame, it will be readily understood that all flames are more or less hollow in structure. In the center is a space occupied by unconsumed gases; surrounding that is the luminous portion of the flame; and outside of all is the non-luminous part, or "mantle," as it is called. The unconsumed inflammable gases can be collected from the center of the flame and afterward ignited, and the mantle can be rendered more visible (according to Bloxam†) by burning sodium near the flame, when the mantle will acquire a strong yellow tinge.

In a blow-pipe flame, the same construction is observed, the flame, however, being diminished in size and luminosity; but by mixing air with gas before ignition, the three portions of a flame are reduced to two, with a considerable reduction in the luminosity of the flame. The combustion becomes complete at an earlier period, and the luminous cone has the same character as the mantle in the former case.

Temperature and Propagation of Flame.—Some interesting observations made by Deville§ on the flame of carbonic oxide burned with oxygen show the chemical composition of the gases at various parts of the flame. He found that when a mixture of carbonic oxide and oxygen in the combining proportions (2 vols. CO to 1 vol. O) was allowed to issue, under a slight pressure, from a jet having an area of 5 square mm., a

flame of 70 to 100 mm. high was formed, consisting of an inner and an outer cone. The outer cone, in which combustion takes place, was deep blue at the base and yellowish or nearly colorless toward the apex. In the inner cone, which was only 10 mm. high, no combustion took place, because the rapidity of displacement of the particles of gas was there superior to the very slow rate of propagation of heat in the mixture.

To collect the gases from the different parts of the flame, a silver tube, pierced with a small aperture, was placed across it in the part to be examined, and the gases were aspirated by passing a rapid stream of water through the tube. They were thus quickly cooled, and, passing along the tube together with the water, were collected, by means of a bent delivery tube, in jars over water.

The following table gives the results of the various observations, the first column giving the positions of the silver tube above the orifice from which the gases issued, the second column the temperatures approximately at these points, and the last division of the table the composition of the gas at the different portions of the flame:

Height above Orifice.	Corresponding Temperatures.	Composition of the Gas.		
		CO.	O.	CO ₂
Mm.				
67	Melting heat of silver, and above	0.2	21.3	78.5
54	Melting heat of gold.	6.2	25.1	65.7
44	Commencing white heat of platinum.	10.0	20.0	70.0
35	White heat of platinum.	17.3	24.8	57.9
29	Strong white heat of platinum.	19.4	26.5	54.1
18	Intense white heat of platinum.	29.0	25.1	45.9
15	Incipient fusion of platinum.	40.0	32.9	27.1
12	Melting point of platinum.	47.0	36.0	17.0
(1) 10	Sparkling of the melted platinum.	55.3	35.3	9.4
(2) 10	Still higher temperature.	55.1	36.5	8.4
(3) 0		64.4	33.3	2.3

(1) A little above the apex of the inner cone.

(2) Somewhat below the apex of the inner cone.

(3) Original mixture.

These numbers show that the highest temperature is at the apex of the inner cone, or a little below it; that the temperature gradually diminishes toward the apex of the flame; and that the quantity of carbonic anhydride increases in the same proportion from the apex of the inner cone, where, at most, two-thirds of the carbonic oxide and oxygen enter into combination, to the vertex of the flame itself, where carbonic oxide can no longer be detected. At the apex and edges of the inner cone the carbonic oxide and oxygen unite almost instantaneously, but only partially, on account of the very high temperature there existing. Bunsen also carefully investigated this subject, and introduced some modifications of the views held previously. Watts (Dict. of Chem., i. 560, Affinity) has summarized this matter as follows: When a combustible gas mixed with oxygen is set on fire, a rise of temperature takes place, which, supposing the combustion to be perfect, may be calculated from the heat of combustion of the gases and the specific heat of the products. If, on the other hand, the combustion is imperfect, the temperature may still be calculated with the aid of Mariotte's and Gay-Lussac's laws, provided the pressure exerted by the gaseous mixture when exploded in a closed vessel be known. This pressure has been determined by Bunsen for mixtures of hydrogen and carbonic oxide with oxygen, or with oxygen and nitrogen together, by means of an eudiometer having a loaded safety valve. From this and the observed temperature of combustion, the quantity of the combustible gas (carbonic oxide or hydrogen) which has been burned at the moment when the flame attains its maximum temperature, and thence also the quantity which at this temperature has lost its power of combining, may be calculated.

The following table contains the results of Bunsen's experiments arranged according to the maxima of temperature ($t-t$) which the several gaseous mixtures, calculated for volumes at 0° C., attain by combustion in a closed vessel. Columns I and II give the mixtures of gases used; $\frac{P}{P_0}$ = the pressure produced in atmospheres by explosion; t = the calculated temperatures; and k = the calculated proportion of combination.

No.	Mixtures of Gases.		$\frac{P}{P_0}$	t	k	Mean.	Deviation from Mean.
	I.	II.					
1	1½ vol. CO + ½ vol. O		10.78	3,172	0.351		+0.0194
2	" " " " " " " "		11.19	3,893	0.319		-0.0126
3	" " " " " " " "		9.97	2,854	0.338		+0.0064
4	" " " " " " " "		9.75	2,833	0.336		-0.0044
5	" " " " " " " "	O+0.1079 vol. O.	9.05	2,558	0.314		-0.0176
6	" " " " " " " "	O+0.6857 " CO.	8.89	2,471	0.460		-0.0421
7	" " " " " " " "	O+0.8854 " O.	8.44	2,325	0.478		-0.0241
8	" " " " " " " "	O+1.0861 " O.	7.86	2,117	0.490		-0.0121
9	" " " " " " " "	O+1.2563 " N.	7.73	2,084	0.515		-0.0129
10	" " " " " " " "	O+1.2599 " N.	7.49	2,021	0.547		-0.0449
11	" " " " " " " "	O+1.2563 " N.	7.35	1,909	0.470		-0.0321
12	" " " " " " " "	O+1.7145 " O.	6.67	1,726	0.520		+0.0179
13	" " " " " " " "	O+2.1559 vols. O	5.83	1,460	0.512		+0.0099
14	" " " " " " " "	O+3.1629 " CO.	4.79	1,146	0.527		+0.0249

These numbers, in Bunsen's view, show that, in a mixture of carbonic oxide or hydrogen with the exact proportion of oxygen required for combustion, and unmixed with any diluent gas, only one-third of the carbonic oxide or hydrogen is burned at the maximum temperature, while the other two-thirds, by being raised to the high temperatures of 2,558° to 3,033°, have lost the power of combining; moreover, that, when

one volume of the same mixture is diluted with 0.686 to 3.163 volumes of any gas that does not burn with it, and the temperature of the flame is successively reduced thereby from 2,471° to 1,146°, then, at all temperatures within these, exactly half of the carbonic oxide or hydrogen is burned, the other half having lost the power of combining.

From this it has been inferred that the combustion of gases takes place in a manner different from that which had been previously supposed. When a mixture of two volumes of carbonic oxide with one volume of oxygen is set on fire, and its temperature thereby raised from 0° to 3,033° C., two-thirds of the carbonic oxide remains in an unburned and, for the time, incombustible state. The temperature is then lowered by radiation and conduction from 3,033° to 2,558° without any combustion of the carbonic oxide, but when the temperature falls somewhat lower, combustion recommences, restoring the heat lost by radiation and conduction, and raising the temperature again to 2,558°, but not above that point. The gradual fall of temperature from 3,033° is followed by a continuance of the temperature 2,558° till exactly half the carbonic oxide is burned, whereupon a third phase sets in, during which, again, no combustion takes place until the inflamed gaseous mixture has cooled down to at least 1,146°. As, however, the gaseous mixture, after cooling, consists almost wholly of carbonic anhydride, these alternate phases of constant and decreasing temperature must be repeated below 1,146° until the last portion of the gas is burned. This discontinuous combustion of a uniform mixture of a combustible gas with oxygen is referred by Bunsen to a law of combination established by him.

These facts, as observed by Bunsen, are of great importance in connection with the inflammation of gases, although it is probable, as Berthelot has indicated, that Bunsen's temperatures are too high in consequence of his not having considered the contraction of volume due to combination.

Berthelot* announced that the combustion temperatures in Bunsen's experiments may be anything between the limits shown in the following numbers, keeping the same numerical order as in the foregoing table:

No.	t^1	t^2	No.	t^1	t^2
1	4,140	2,612	8	2,280	1,875
2	3,900	2,537	9	2,203	1,838
3	3,809	2,449	10	2,126	1,715
4	3,718	2,389	11	2,083	1,734
5	3,066	2,198	12	1,875	1,548
6	2,760	2,154	13	1,505	1,319
7	2,537	2,031	14	1,150	1,034

A number of experiments on this subject have been made since Berthelot's criticism appeared, but the conclusions arrived at are contradictory. All, however, agree in observing a great absorption of heat at high temperatures, which is thought to be due either to a change in the specific heat of gases or to dissociation. Messrs. Berthelot and Vieille† and Mallard and Le Chatelier‡ have advanced and supported the former view, while the latter has been advocated by Mr. Dugald Clerk§ and Professor Rucker, of Leeds. It is probable that both causes operate to produce the phenomena which have been observed.

The rate of ignition of gaseous mixtures is also a point of considerable importance. Sir H. Davy‡ propounded a theory of this action, but it does not seem to be entirely supported by more recent investigations.

Bunsen found that the velocity of the propagation of combustion in a pure detonating mixture of hydrogen and oxygen was 34 meters per second, and in a maximum explosive mixture of carbonic oxide and oxygen it was less than one meter per second. When the explosive gases are gradually diluted with a gas that does not take part in the combustion, the rate is lowered, and it can be brought down thus until the progress of combustion is made visible to the eye.

Bunsen's method of determining these velocities is thus described by Dugald Clerk (*loc. cit.*): The explosive mixture was allowed to burn from a fine orifice of known diameter, and the rate of the current of the gaseous mixture was carefully regulated by diminishing the pressure to the point at which flame passed back through the orifice and ignited the gases below it. This passing back of the flame occurs when the velocity with which the gaseous mixture issues from the orifice is inappreciably less than the velocity with which the inflammation of the upper layers of burning gas is propagated to the lower and unignited layers.

Professor Mallard,¶ of the Ecole des Mines, made a series of observations by this method on the rate of the propagation of combustion in mixtures of coal gas and air and of marsh gas and air. In the latter mixtures, the maximum rapidity of inflammation was found to be about 0.56 meter, or rather more than half a yard, per second. This velocity was attained with a mixture of 1 vol. marsh gas and 8½ vols. air. When the proportion of air was increased to 12 vols. or diminished to 5.9 vols., the mixture was neither explosive nor inflammable.** Professor Thorpe remarks on this that it is worthy of note that the proportion of air corresponding with the maximum rate of inflammation is less than that which contains oxygen sufficient for the complete combustion of the marsh gas. This, however, is what the observations by Bunsen and others, previously quoted, would lead us to expect.

The maximum rapidity of inflammation in mixtures

* "Ann. de Chim. et Phys." [5], vol. xii., pp. 302-310; "J. Chem. Soc.," vol. xxxiv., p. 5; "Compt. Rend.," vol. lxxiv. (1887), p. 407.

† "Essai de Mécanique Chimique," Paris, 1879; "Ann. de Chim. et de Phys.," 5^{me} sér., xxvii and xxviii; 6^{me} sér., iv., pp. 13-84.

‡ "Compt. Rend." 1880, 1881, vols. xci., xciii.; "Annales des Mines," 8^{me} sér., "Mémoires," iv., p. 274.

§ On the Theory of the Gas Engine, "Min. Proc. Inst. C. E.," vol. lxxx., part iii., also *ibid.*, vol. lxxxv., pp. 1-53. See also Rossetti, "On the Temperatures of Flames," "J. Chem. Soc.," vol. xxxiv., pp. 407, 494, etc.

¶ "Recherches on Flame." See also Watts, Dict. of Chem., Combustion, i., 1089.

** "Annales des Mines," vol. vii., 1875, p. 355. Thorpe, on the "Theory of the Bunsen Lamp," "J. Chem. Soc.," 1877, i., p. 631.

See also "On the Theory of the Bunsen Lamp," "J. Chem. Soc.," 1877, i., p. 166, and in "Compt. Rend.," 1876, vol. xxxiii., p. 709.

* A paper read before the Society of Chemical Industry, Glasgow, March 5, 1889. From the *Journal of the Society*.

† This is true of single pieces of carbon—a mass of carbon burning in air or oxygen generally shows a lambent blue flame on the surface, which is due to the burning of carbonic oxide, CO, formed by the reduction of the carbonic anhydride, CO₂, in its passage through the glowing carbon.

‡ "Chemistry," edition 1867, p. 95.

§ "Bull. Soc. Chim.," [2], v. iii.; also Watts, "Dict. of Chemistry."

* See also Thorpe on the Theory of the Bunsen Lamp, "Jour. Chem. Soc.," 1877, i., p. 627, for Bloxham's investigations, or "Annalen Chem. Pharm.," vol. clxviii., p. 295.

† "Phil. Mag.," vol. xxxiv., p. 489, and "Gasometry," by R. Bunsen.

of coal gas and air was attained with a mixture of 5 vols. of air and 1 vol. of coal gas, and was 1.02 meter, or rather more than 1 yard, per second. One volume of coal gas with 6½ vols. of air gave a rate of 0.285 meter, or 11 inches, per second. The rate was very rapidly diminished by an excess of either constituent; a mixture containing more than 8 vols. and less than 3½ vols. of air to 1 of coal gas was found to be unflammable in the way described.*

Dugald Clerk has pointed out that these are the rates of ignition at constant pressure, and that in a closed space the conditions of inflammation are quite different in consequence of the expansion of the ignited portion and mechanical disturbance of the remaining part of the gaseous mixture. Experiments are needed to determine the rate of ignition for constant volume. Some remarkable results are given by this author, which were obtained by so arranging the plan of ignition that a small volume of gases was first ignited, which expanded and projected a flame through a passage into the mass of an inflammable mixture, thus adding to the rate of ignition the mechanical disturbance produced by the entering flame. He succeeded by this means in producing maximum pressure (or maximum ignition) in ⅓ part of a second in a space containing 200 cubic inches of gas. By firing a mixture with varying amounts of mechanical disturbance, almost any time of ignition could be obtained between ⅓ and ⅓ of a second. It did not matter whether the mixture used was rich or weak in gas; the rich mixture could be fired slowly, and the weak one rapidly, just as was required. He found that the rate of ignition of the strongest possible mixture is so slow that the time of attaining complete inflammation depends on the amount of mechanical disturbance permitted.

Mr. Lewis T. Wright has recorded, some interesting observations on the velocity of the propagation of flame, and has announced that, when flame travels at a greater velocity than 4½ feet per second, it will pass through the gauze used in safety lamps. He also found that a flame of low velocity in a confined space may become so much agitated by an increase in its own oscillations as to cause the introduction of a very rapid rate of ignition in the remaining portions of the gaseous mixture. He remarks that "a definite explosive mixture may have a velocity of propagation of flame, when it is undergoing explosion of the first order, as low as 1½ feet per second; but when it becomes sufficiently agitated to give an explosion of the second order, the rate of propagation of flame is several thousand feet per second."

The following table shows the results of experiments with various mixtures of gases, giving the rate at which an explosion of the first order (that is, a slow ignition) travels with each mixture in a glass tube 13 feet long and 0.75 inch diameter:

Mixtures.		Lineal Velocity of Efflux of Mixture.	Rate at which Explosion of First Order Travels in Tube.	Total Velocity of Propagation of Flame.
Gas.	Air.	Feet Per Second.	Feet per Second.	Feet per Second.
Per cent.	Per cent.			
10.3	89.7	1.21	1.1	2.31
12.2	87.8	1.24	2.0	3.24
15.0	85.0	1.28	3.0	4.28
17.7	82.3	1.33	4.8	6.13
19.6	80.4	1.35	3.0	4.35
21.2	78.8	1.38	2.4	3.78
22.1	77.9	1.39	1.3	2.69
23.0	77.0	1.41	Stationary.

Wright also found that whenever an explosion is produced inside a safety lamp having ordinary gauze, the flame was projected through the gauze, and could ignite gas at a considerable distance from the lamp. By employing stiff wires for the wool and lighter wires for the warp, he produced a "basket work" gauze having small, tortuous openings and a relatively large weight of metal, which did not allow flame from an explosion to pass through.

Luminosity of Flames.—According to the commonly received theory of the causes of luminosity in flames (first propounded by Sir H. Davy†), the presence of solid particles suspended in the flame (or in immediate contact with the burning gas) is essential to its luminosity.

There is no doubt that the introduction of solid particles in a fine state of division into a flame of feeble luminosity will impart to it a considerable degree of brilliancy by the incandescence of the solid particles, or perhaps in some cases by reflection of the light from their many surfaces. No sound conclusion, however, as to the luminosity of flames in general can be drawn from such an analogy as is afforded by the result of such an experiment, because Tyndall has shown that the same result is produced when the solid introduced is one that does not burn. The presence of solid particles, according to the common idea, in luminous flames is only assumed, not proved. It is usual, however, to refer to the black deposit which is formed upon a glass rod or similar body, when it is held in the flame of a candle or of hydrocarbon gas, as a proof that such flames contain solid particles. This, however, is not a conclusive proof, for Dr. Frankland§ has pointed out that this deposit is not pure carbon, but is a hydrocarbon compound. To this Dr. Percy|| objects that it is fixed, not volatile, whatever its composition may be; but the objection seems to be irrelevant, because it refers to the substance as deposited, and we do not know that such a substance existed in the flame. The introduction of the cold surface of the glass rod not only condenses some vaporous hydrocarbon, but doubtless also causes decomposition of some of the many hydrocarbons which make their appearance in

the gradual resolution of carbonaceous matter. As, therefore, we do not know in what combination this substance producing the black deposit existed while it was originally in the burning gas, it cannot properly be asserted that it was "fixed, not volatile."

The phenomena of many luminous flames are explained by various writers, with more or less ingenuity, on the hypothesis of solid particles, but the experiments and observations of Dr. Frankland* have shown that that hypothesis is not wholly satisfactory, because luminous effects have been produced where it could not account for them, such, for example, as the luminosity of the flame of hydrogen burning in oxygen under pressure; and secondly, because in many of the brightest flames the temperature is such that fuliginous matter† could not exist in them. In many cases, it might seem, therefore, to be a more satisfactory explanation, that the luminosity of flames depends on the existence of a comparatively high temperature and on the presence of gases or vapors of considerable density.‡

Soret§ made, in 1874, some experiments which were intended to refute the opinion previously given by Hirn adverse to Davy's theory of solid particles. These experiments consisted in projecting, by means of lenses, the image of the sun on to the surface of several hydrocarbon flames, and examining the degree of polarization of the reflected light by the use of a Nicol's prism. As the light was observed by the eye, it was necessary to interpose several plates of cobalt-colored glass, and the sunlight was distinguishable from the light of the flame merely by means of a trace of blue which was ascribed to it as distinct from the purple color yielded by the flame light.

Soret obtained similar results, though in varying degree, with sunlight when reflected from lampblack, from non-incandescent smoke, from smoky carbon flames, and from the flames of candles and hydrocarbon gases having different degrees of carburization. When, however, the flame, even of highly carburized gas, burned in an atmosphere of abundant oxygen, the blue trace and polarization effect were invisible. In fact, his best results were obtained in proportion to the decrease of luminosity. On this account Soret was not warranted in concluding, as he did, that his results support Davy's theory, because they failed just when it was important that they should not fail, namely, when the luminosity of the flames was largely increased. If we accept these experiments as showing that sunlight was reflected from finely divided particles in these flames, they also indicate that the luminosity of these flames was not only *not due* to the presence of these solid particles, but that, on the contrary, it was *diminished* by them, as they disappeared from the brighter flame.

More recently Burch|| has to some extent repeated Soret's experiments, making use, however, of the spectroscopic examination of the light from the flame, and thus being better able to distinguish between it and the reflected sunlight. He found that the reflected sunlight showed all the Fraunhofer lines, and that, on using the Nicol's prism, it was polarized at right angles to the line of incidence; and he compared this result with that obtained from the reflection from finely divided particles of shellac as precipitated by and suspended in water.

The observed effects being the same, he was perhaps justified in concluding that in the flames which he examined, the sunlight was reflected from finely divided solid particles; although in the present state of this branch of the science of optics, it would be foolish to consider this matter *proved*. Finely divided solid matter suspended in a viscous fluid, and rushing through a flame, represent very different physical conditions, and it is extremely improbable that we can safely reason from results afforded by one phenomenon to those of the other. The flame itself, by reason of the intense vibrations which constitute its existence, may behave toward sunlight in a manner very different from that of a transparent and almost quiescent liquid.

At any rate, Burch's results are far from proving that the luminosity of these flames was in any way dependent upon the presence of solid particles, except in so far (as Soret's experiments teach) as they may have acted in diminishing the degree of luminosity. The mere fact of the *presence* of solid particles, supposing that to be established, does not prove anything regarding any relation between them and luminosity. This is a distinct subject for proof.

On the other hand, the effect of high temperature is seen in the greater brightness of the flames of sulphur, phosphorus, and, indeed, all substances when burnt in pure oxygen, as compared with the result of their combustion in air. Direct evidence of the effect of high temperature is also afforded by the combustion of phosphorus in chlorine, for while at ordinary temperatures only a feeble light is produced by this combustion (although the product PCl₃ has considerable density), strongly heated phosphorus vapor burns in hot chlorine with a dazzling white light.

A comparison of the relative densities of gases and vapors shows that the brightest flames in general are those which contain the densest vapors.

Relative Densities of some Gases and Vapors.

Hydrogen.....	1
Water.....	9
Hydrochloric acid.....	18½
Arsenious chloride.....	9¾
Metallic arsenic.....	150
Arsenious oxide.....	198
Air.....	14.5
Oxygen.....	16
Carbon dioxide.....	22
Sulphur dioxide.....	32
Phosphoric oxide.....	71 or 142
Chlorine.....	35.5
Mercury.....	200

* *Op. cit.* and "J. Chem. Soc." Lond., 1864, vol. xvii., pp. 52-55; *Brit. Assoc. Reports*, vol. xxxviii., p. 37; "Proc. Roy. Inst.," vol. v., 1869, pp. 419-423; "Proc. Roy. Soc.," Lond., vol. xxx., No. 201.

† See *Lectures on Coal Gas*, delivered at the Royal Institution, London, March, 1867, by Dr. Frankland, published in the "Jour. of Gas Lighting," etc., London.

‡ "Jour. Soc. Chem.," 1862, vol. xv., p. 168; Watts, "Dict. of Chemistry," 1st sup., p. 485.

§ "Phil. Mag.," ser. 4, vol. xlvii., p. 205; vol. 1875, p. 50. Translated from "Archives des Sciences" of the "Bibliothèque Universelle," 1873 and 1874.

|| "Nature," vol. xxxi., p. 272.

Hydrogen burning in chlorine produces a vapor more than twice as heavy as that resulting from its combustion in oxygen, and accordingly the light produced in the former case is stronger than in the latter. Carbon and sulphur burning in oxygen produce vapors of still greater density (viz., CO₂ and SO₂), and their combustion gives a still brighter light. Phosphorus, also, which has a very dense vapor, and yields, in burning, a product of great vapor density, burns in oxygen with a brilliancy almost blinding.

The luminosity of a flame is increased by compressing around it the surrounding gaseous atmosphere, and it is diminished by rarefying it. 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 vessels so as to prevent expansion of the gases at the moment of combustion.

Frankland experimented with jets of hydrogen and carbonic oxide burning in oxygen under a pressure which he gradually increased to twenty atmospheres, and obtained brilliant luminous effects, including bright and continuous spectra. Even the faint flame of alcohol, as in an ordinary spirit lamp, becomes highly luminous under the receiver of a condensing pump, when the pressure of air is increased to 120 inches of mercury.

We are indebted to Frankland* also for the observation that the diminution in illuminating power is directly proportional to the diminution in pressure; and, as applied to ordinary domestic gas burners, this means that, as the barometer falls, the light from them diminishes at the rate of 51 per cent. for every inch of fall. According to Dr. Letheby,† in London the difference in the value of the light when the barometer is 31, as compared with what it is at 28, is fully 25 per cent."

The flame of arsenic burning in oxygen may also be rendered quite feeble by rarefying the oxygen; and, at high altitudes, flames exhibit the effects of rarefied air. Tyndall and Frankland‡ made observations on the combustion of stearin candles at the summit of Mont Blanc and at Chamouni, and found a considerable decrease in luminosity at the high elevation, although the rate of combustion of the candles remained the same in both places. The energy of combustion was therefore unaltered, although the flame in one case had a higher temperature than in the other, resulting from the increased density of the gaseous atmosphere. Percy shows (vol. "Fuel," p. 159) that this conclusion should be drawn even from the theory propounded by Tyndall in explanation of the diminished luminosity which he observed on Mont Blanc. Tyndall's theory was that the decrease in luminosity was mainly due to the greater mobility of the air. From this Percy reasons, "Now, if increased mobility of the air be caused by rarefaction, the opposite should result from compression, in which case the movement of the particles would become sluggish, intermixture of the air and flame producing gas would be less rapid, and the diffusion of the gaseous products of combustion in the surrounding air would be retarded, with consequent increase of temperature."

Frankland's conclusions have also been confirmed by some experiments by Professor V. Wartha§ on the influence of pressure on flames.

[FROM INSECT LIFE.]

THE HABITS OF THALESSA AND TREMEX.]

By C. V. RILEY.

STRUCTURE OF THE OVIPOSITOR.

OUR readers who have followed us so far will doubtless wonder how an egg can be passed down such a long ovipositor not wider than a horse-hair. A careful examination will show that this instrument is composed of three parts, which may, upon being softened, easily separate, but which in nature are securely locked together. Fig. 3 illustrates the ends of these three

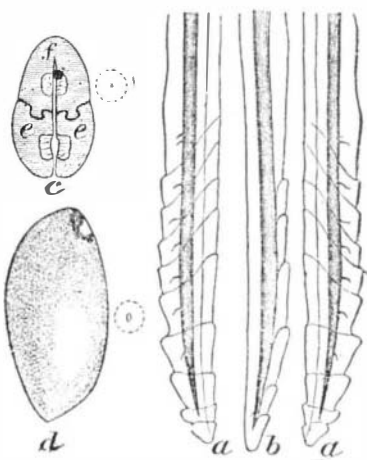


FIG. 3.—OVIPOSITOR AND EGG OF THALESSA.

a, b, a, tips of component parts of ovipositor proper; c, cross section of ovipositor; d, egg; e, e, ventral pieces of ovipositor proper; f, middle or dorsal piece of ovipositor, all greatly enlarged (original).

parts, a, a, b, as they appear when on their flat sides, and it will be noticed that the tips are strongly notched diagonally, which structure facilitates the insertion or boring into the tree and renders extraction somewhat more difficult, especially where the wood is somewhat hard. Now the dorsal or central piece is solid at its dorsal end and cleft on the inner side to about two-thirds or three-fourths its length. On either side of this cleft is a strong ridge or rail something after the fashion of a T-rail. Each of the ventral pieces, on the contrary, has a groove into which the rail-like ridges of the dorsal piece lock. The ventral pieces in the act of oviposition slide up and down these rails, which

* *Op. cit.* and "Phil. Trans.," vol. cli., 1861, p. 629.

† "Common Sense for Gas Users," by R. Wilson, p. 19 (London: Crosby, Lockwood & Co.)

‡ "Heat considered as a Mode of Motion," by J. Tyndall, F.R.S., 1865, p. 50.

§ "Jonr. für Gasbeleuchtung," vol. xix., p. 761; "Min. Proc. Inst. C.E.," vol. xlviii., part ii., p. 329.

‡ Continued from SUPPLEMENT, No. 700, page 11188.

* "Compt. Rend.," vol. xcv., pp. 151-157; "Ann. de Chim. et Phys.," [6], vol. vi., 1885, pp. 546, 556.

† "J. Soc. Chem. Ind.," vol. vi., pp. 302-304.

‡ "Phil. Trans.," for 1817, p. 75.

§ "Proc. Roy. Soc.," Lond., vol. xvi., 1868; "Phil. Mag.," vol. xxxvi., 1868, pp. 309-311; "Experimental Researches," "Lectures on Coal Gas,"

|| "Metallurgy," vol. "Fuel," p. 158.