

formula of Clausius, $\left[\frac{P}{P_0} + \frac{b}{T \left(\frac{V}{v_0} + c \right)} \right] \left(\frac{v_0}{v} - w \right) = \frac{T}{273}$ Where b , c , and w are coefficients

peculiar to each gas. For high temperatures, and as long as the ratio $\frac{V}{v_0}$ is not too small, the expression $\frac{c}{T \left(\frac{V}{v_0} + c \right)}$ may be practically eliminated. The coefficient w , which may be called the Co volume, is nearly the same for all gases, as shown by the experiments of Mr. Amagat and the calculations of Mr. Sarrau, and may be taken as equal to 0.001. Therefore $\frac{P}{P_0} \left(\frac{V}{v_0} - w \right) = \frac{T}{273}$. It is remarked that with a charging density d , then $V = \frac{w}{d}$; then this formula becomes

$$P = \frac{\frac{P_0 v_0 T}{w \times 273} d}{1 - \frac{v_0}{w} d} = \frac{fd}{1 - ad},$$

in which the coefficients f and a can be calculated, so that the theoretical figures may be compared with the experimental values.

Comparison of Theoretical with Experimental Pressures.—This comparison is made more simple if the last equation is put in form $\frac{P}{d} = ap + f$. The line which has $\frac{P}{d}$ for ordinates and P for abscissar should be a straight line, whose angular coefficient is a and the ordinate at the commencement f . Fig. 8 shows the positions of these straight given by this equation for nitrate of ammonia, dynamite, gun-cotton, a mixture of 60 per cent. of nitrate of ammonia with 40 per cent. of military cotton, the Favier explosive, endecanitrilic cellulose, and picric acid. Each of these lines has been traced with the calculated angular coefficient a . The dotted line in the figure is a theoretical line; the continuous line is drawn as near as possible to the experimental points, always with the same angular coefficient a .

The difference between the theoretical and the experimental lines for nitrate of ammonia, the Favier explosive, and the mixture of cotton and nitrate is less than the possible errors of observation and calculation. For dynamite the difference is only $\frac{1}{10}$. This concordance is closer than might have been expected. For gun-cotton the difference is as much as $\frac{1}{10}$, taking the latest pressure-readings quoted by Messrs. Berthelot and Vieille in their paper on fulminates of mercury, in which the results are not perfectly concordant. But in this case a substance is being considered whose chemical composition is uncertain, and, moreover, whose method of decomposition on explosion is doubtful. The calculations have been made by accepting the mode of decomposition not actually observed but assumed by Messrs. Sarrau and Vieille as being the limit towards which the observed mode tends. The observations relative to picric acid are found to lie very nearly on a line, having the calculated inclination a . The difference between this line and the theoretical line is similar to that shown by gun-cotton. Picric acid is also a substance whose manner of decomposition is doubtful.

These examples amply prove that the method of calculation represents the facts almost exactly. The temperature and pressure developed by the detonation of any explosive of known composition can therefore be calculated with sufficient exactness, provided that the method of decomposition of this explosive when detonated is known. The calculated curves in 5, 6, and 7 therefore represent the phenomena somewhat correctly if the decomposition of the explosive occurs conformably with that assumed in the calculation.

Experimental Study of the Unconfined Detonation of Explosives.

Incomplete Detonation of Unconfined Explosives.—Experiment has shown that a mixture containing 67 per cent. of dynamite and 33 per cent. of sal ammoniac ignites firedamp; that a mixture of 40 per cent. of sal ammoniac ignites it seldom, and that a mixture of 50 per cent. of sal ammoniac does not ignite it. Now, if the curve which represents the temperatures of detonation of these mixtures be continued downwards the mixture of 33 per cent. of sal ammoniac will develop a temperature of 2,732° Fahr.; the 40-per-cent. mixture a temperature of 2,012° Fahr., and the 50-per-cent. mixture 743° Fahr., if the decomposition can be considered as complete in each case. Moreover, this assumption is certainly incorrect for the 50-per-cent. mixture, because at the temperature of 743° Fahr., sal ammoniac is not decomposed. Admitting the correctness of the hypothesis for other mixtures, it may be concluded that the temperature which the gases from the explosive should not surpass to ignite the firedamp is lower than 2,912° Fahr. This deduction is not correct, as will be shown hereafter. Lastly, it may be said that explosives, especially if they consist of dual mixtures, on the contrary, are not always decomposed in a complete manner when exploded unconfined.

Method of Experiment.—It is interesting to study this fact with precision. For this purpose the amount of heat developed by the detonation of an unconfined explosion was measured in some way, transforming the boiler into a calorimeter. A cartridge, exactly weighed, is fired in the boiler, closed, and filled with air. A water-gauge is used to measure at known intervals, starting from the moment of firing, the excess pressure, $P' - P$, of the air in the boiler above the initial pressure. A curve representing these observations is used to determine, by extension, the pressure exerted at the moment of detonation, which cannot be correctly observed on account of the shock imparted at the moment to the water in the water-gauge. Fig. 9 shows examples of the curves so drawn. The precise significance of the figured curves will be indicated further on.

N=the curve of the pressure for a cartridge containing 772gr. of dynamite unconfined;
T=curve for a cartridge 772gr. dynamite contained in a tube of 0.98in. and 15.7in.

The measurements thus made are evidently inexact; however, they are sufficient for the desired object.

The volume of the boiler being 359.2 cubic feet, the volume of the gases resulting from the explosion of the cartridge—the weight of which is from 772 to 1543 gr.—is relatively insignificant.