

tical value of the forecasts to be established. This can only be done by trial, and both sides are waiting for the other to demonstrate, beyond cavil, the value of the information to be supplied. The fundamental difficulty seems to be that the farmer has made his own study of the weather, and uses it in his own way without committing the results to writing, while the Meteorological Office prints large masses of data without knowing precisely in what directions to discuss them in relation to agricultural problems.

Appendix 4 deals with proposals for the establishment of a "Central Observatory for the Investigation of the Upper Air," in which it is pointed out that since 1905 the small sum of 450*l.* a year has been available for the purpose of upper air research. Having in view the great and rapidly growing importance of the aeronautical and aerological aspects of the work, especially in relation to aviation, it is to be hoped that this scheme will go through. The services rendered by Mr. W. H. Dines, F.R.S., in the past are so well known that the mere mention of them is an ample guarantee that the annual appropriation of some 1000*l.* to 1500*l.* proposed would be money well expended. The site suggested is at Benson, in Oxfordshire, which has many advantages to recommend it as a position for the central aeronautical observatory contemplated.

THE NATURE OF EXPLOSIVES.

IT was suggested in the review of Mr. A. Marshall's important work on "Explosives" in *NATURE* of June 3, 1915 (vol. xcv., p. 366) that the book would be improved if it had an introductory chapter dealing with the general principles on which the composition and action of explosives depend. Mr. Marshall, writing from Naini Tal, India, says that he had prepared a chapter on the lines suggested for another shorter work of a less technical character than that which was the subject of our review. Unfortunately, through pressure of other work, he has been obliged to postpone for the present the completion of this book, but he sends us the chapter; and we are glad to publish it as a separate article, as the subject is of particular interest at the present time.

EXPLOSION.—When gas or vapour is released so suddenly as to cause a loud noise an explosion is said to occur, as, for instance, the explosion of a steam boiler or a cylinder of compressed gas. Great and increasing use is made of explosive processes in gas, petrol, and oil engines for driving machinery of all kinds. In these engines the material that explodes is a mixture of air with combustible gas, vapour, or finely-comminuted liquid, and in the explosion these are suddenly converted into water vapour and the oxides of carbon, which latter are gases. Although all these things are liable to explode, none of them are called explosives; this term is confined to liquid and solid substances, which produce much more violent effects than exploding gaseous mixtures, because they occupy much smaller volumes originally.

EXPLOSIVE.—An explosive is a solid or liquid substance or mixture of substances which is liable, on the application of heat or a blow to a small portion of the mass, to be converted in a very short interval of time into other more stable substances largely or entirely gaseous. A considerable amount of heat is also invariably evolved, and consequently there is a flame.

GAS EVOLUTION.—That evolution of gas (or vapour) is essential in an explosion is rendered evident by considering thermit. This consists of a mixture of a metallic oxide, generally oxide of iron, with aluminium powder. When suitably ignited the

aluminium is converted into oxide and the iron or other metal is set free in a very short interval of time with the evolution of an enormous quantity of heat, but there is no explosion. It is indeed because no gas is evolved that thermit can be used, as it is, for local heating and welding.

HEAT LIBERATION.—It is also an essential condition that heat should be evolved in an explosive reaction, otherwise the absorption of energy due to the work done by the explosion would cool the explosive and consequently slow down the reaction until it ceased, unless heat were supplied from without. Ammonium carbonate, for instance, readily decomposes into carbon dioxide, ammonia, and water, but in so doing it absorbs heat; consequently the reaction is much too slow to be explosive. Ammonium nitrate, on the other hand, is decomposed into oxygen, nitrogen, and water, with the evolution of heat, and is consequently liable to explode. A violent impulse is required to start the explosion, but once it is started the energy (or heat) liberated suffices to propagate the explosion, unless the conditions be such that the energy is dissipated more rapidly than it is liberated.

SENSITIVENESS.—Another essential for an explosive is that the reaction shall not set in until an impulse is applied. If the reaction set in spontaneously, it is obvious that its energy cannot be utilised in the form of an explosion. A mixture of sodium and water evolves hydrogen with the liberation of heat, but reaction sets in immediately the two substances come in contact with one another. Different explosives require impulses of very different strengths to cause them to explode. Some, such as diazobenzene nitrate, are exploded by a slight touch; these explosives are of no practical utility as they are too unsafe. Others, such as fulminate of mercury, are exploded by a moderate blow or a small flame; these are used principally for charging caps and detonators, a small quantity serving to explode a large amount of some other less sensitive explosive. Most of the explosives now used can be exploded by a blow only if it be extremely violent, and many of them cannot be exploded by a flame in the open in ordinary circumstances. The tendency is to use less sensitive explosives because they are safer to handle, but it should never be forgotten that the term "safe," when applied to an explosive, is only a comparative one. The duty of an explosive is to explode, and if it is not treated with proper respect it will, sooner or later, explode at the wrong time with extremely unpleasant results.

Before the subject of explosives was understood so well as it is now, inventors were very liable to think an explosive was very powerful, and therefore valuable merely because it was very sensitive, whereas too great a degree of sensitiveness is really a most objectionable feature. In the middle of the nineteenth century many such mixtures as potassium chlorate and picric acid were proposed through this want of comprehension of a fundamental condition.

CONSTITUENTS OF EXPLOSIVES.—The explosive gaseous mixtures used in gas and oil engines to which reference has been made are composed of a combustible material, consisting largely of carbon and hydrogen, and air, the useful constituent of which is oxygen. Similarly, nearly all commercial explosives are composed partly of combustible elements, of which carbon and hydrogen are the most important, and partly of oxygen combined, but not directly with the hydrogen and carbon. On explosion the oxygen combines with the hydrogen to form water, and with the carbon to form carbon monoxide or dioxide, or a mixture of the two. It is the heat set free in this combustion that is the main or entire cause of the rise of temperature. The formation of these two oxides of carbon liberates very different quantities of heat; 12 grams of carbon

unite with 16 grams of oxygen to form 28 grams of carbon monoxide with the liberation of 29 large Calories, and the same quantity of carbon unites with 32 grams of oxygen with the liberation of 97 large Calories.

Consequently an explosive is considerably more efficient if it contains sufficient oxygen to oxidise the carbon entirely to dioxide, but the effect is reduced to some extent by the relatively high specific heat of carbon dioxide. In some classes of explosives, however, a very high temperature is objectionable; this is the case with smokeless powders and explosives for use in coal mines. Smokeless powders, therefore, are generally made of such a composition that the greater part of the carbon is oxidised only to monoxide. But there is always some carbon dioxide formed, for it takes up some of the oxygen from the water vapour and liberates hydrogen, or if the total quantity of oxygen be very small there may even be free carbon produced. In the case of safety explosives for coal mines, the temperature of explosion is also sometimes kept low by restricting the proportion of oxygen, but this means is not free from objection because carbon monoxide is poisonous. Other methods are therefore adopted in some safety explosives to reduce the temperature.

OXYGEN CARRIERS.—The oxygen may either be contained in a separate compound, such as saltpetre, which is mixed mechanically with the combustible material, or the two may be combined together in a single compound, as is the case with nitroglycerine, trotyl, and many other modern explosives. The substances rich in oxygen are often referred to as "oxygen carriers"; those most used are nitrates, chlorates, and perchlorates, in which the oxygen is united to nitrogen and chlorine respectively. Ordinary gunpowder, or "black powder," belongs to the class of explosives that have separate oxygen carriers, in this case saltpetre. The following table shows the properties of the principal oxygen carriers:—

Oxygen carrier	Molecular weight	Density	Reaction	Heat evolved		Oxygen available		
				per mol.	per 100 grams.	per 100 grams.	per 100 c.c.	
<i>Nitrates.</i>								
Potassium ...	101.1 ...	2.08 ...	$2\text{KNO}_3 = \text{K}_2\text{O} + \text{N}_2 + 5\text{O}$ ...	... -75.6 ...	... -74.8 ...	... 39.5 ...	... 82
Sodium ...	85.0 ...	2.26 ...	$2\text{NaNO}_3 = \text{Na}_2\text{O} + \text{N}_2 + 5\text{O}$ ...	... -60.5 ...	... -71.3 ...	... 47 ...	... 106
Calcium ...	164.1 ...	2.36 ...	$\text{Ca}(\text{NO}_3)_2 = \text{CaO} + \text{N}_2 + 5\text{O}$ ...	... -70.6 ...	... -43.0 ...	... 49 ...	... 115
Barium ...	261.5 ...	3.2 ...	$\text{Ba}(\text{NO}_3)_2 = \text{BaO} + \text{N}_2 + 5\text{O}$ ...	... -94.4 ...	... -36.1 ...	... 31 ...	... 98
Lead ...	331.1 ...	4.58 ...	$\text{Pb}(\text{NO}_3)_2 = \text{PbO} + \text{N}_2 + 5\text{O}$ ...	... -54.6 ...	... -16.5 ...	... 24 ...	... 111
Ammonium ...	80.1 ...	1.71 ...	$\text{NH}_4\text{NO}_3 = 2\text{H}_2\text{O} + \text{N}_2 + \text{O}$ ...	... +27.6 ...	... +34.5 ...	... 20 ...	... 34
<i>Chlorates.</i>								
Potassium ...	122.6 ...	2.00 ...	$\text{KClO}_3 = \text{KCl} + 3\text{O}$ ...	... +11.9 ...	... +9.7 ...	... 39 ...	... 78
Sodium ...	106.5 ...	2.29 ...	$\text{NaClO}_3 = \text{NaCl} + 3\text{O}$ ...	... +13.1 ...	... +12.3 ...	... 45 ...	... 103
Barium ...	304.3 ...	3.18 ...	$\text{Ba}(\text{ClO}_3)_2 = \text{BaCl}_2 + 6\text{O}$ ...	... +25.9 ...	... +8.5 ...	... 31.5 ...	... 100
<i>Perchlorates.</i>								
Potassium ...	138.6 ...	2.54 ...	$\text{KClO}_4 = \text{KCl} + 4\text{O}$ ...	... -7.8 ...	... -5.6 ...	... 46 ...	... 117
Sodium ...	122.5 ...	— ...	$\text{NaClO}_4 = \text{NaCl} + 4\text{O}$ ...	... -12.4 ...	... -10.2 ...	... 52 —	
Barium ...	336.3 ...	— ...	$\text{Ba}(\text{ClO}_4)_2 = \text{BaCl}_2 + 6\text{O}$ ...	... -4.3 ...	... -1.3 ...	... 38 —	
Ammonium ...	117.5 ...	1.89 ...	$2\text{NH}_4\text{ClO}_4 = 2\text{HCl} + 3\text{H}_2\text{O} + 5\text{O}$ ...	... +29.5 ...	... +25.1 ...	... 34 ...	... 65

It will be seen that the proportion of available oxygen is about the same in the chlorates as in the corresponding nitrates, but whereas the chlorates decompose with the evolution of a small amount of heat, the nitrates require a considerable amount of heat to split them up, except in the case of the ammonium compound. Explosives containing chlorates are consequently much more powerful than those containing nitrates, but they are also very sensitive unless special measures are adopted to render them more inert. The perchlorates require considerably less heat to decom-

pose them than the nitrates, and have more available oxygen. As they are now produced at quite low cost by electrolytic methods, it is not surprising to find that they are being used more and more for the manufacture of explosives. Ammonium nitrate and perchlorate decompose with the evolution of heat, this being due to the formation of water, but the available oxygen is diminished by the same cause. Ammonium nitrate can be detonated by itself, although only with difficulty, and then gives a large volume of gas at a comparatively low temperature. In consequence of this low temperature it has been found very useful as a constituent of safety explosives for use in coal mines, but it also forms part of many other high explosives. Ammonium perchlorate suffers under the disadvantage that amongst its products of explosion is the poisonous gas, hydrogen chloride, or hydrochloric acid.

Potassium permanganate and bichromate have also been used, but they possess no special advantages. Permanganate explosives are often inconveniently sensitive. Attempts have also been made to use liquid oxygen, which has the advantage of being cheap and containing 100 per cent. of available oxygen, but the difficulties of employing a liquid which boils at 200° C. below the ordinary temperature are so great that these attempts were given up. The Germans are, however, making great efforts to develop these explosives for work in mines, so as to set free a corresponding quantity of nitrates for military use. For the same reason the German authorities are encouraging the use of chlorates and perchlorates.

COMBUSTIBLE CONSTITUENTS.—In black powder the combustibles are charcoal and sulphur; in blasting explosives many sorts of organic matter have been used or proposed, and some inorganic substances, such as potassium ferrocyanide, ammonium oxalate, and antimony sulphide, but those in common use are not very numerous. For explosives containing nitroglycerin an absorbent material must be used, and of

these wood meal is the most usual, but flour and starch are constituents of some nitroglycerin explosives, and in a few cases such substances as tan meal and prepared horse-dung are present. Cork charcoal has great absorptive power, but its high cost prevents its use. Ordinary charcoal is a constituent of some explosives, as also is coal-dust. American dynamites often contain resin and sulphur, and these constituents are sometimes met with in other explosives. Oily materials, such as castor oil, vaselin, and paraffin wax, reduce the sensitiveness of an explosive, and one or

other of them may usually be found in a chlorate blasting explosive. The addition of aluminium greatly increases the heat of explosion; it is present in the explosives of the ammonal type.

NITRO-AROMATIC COMPOUNDS.—Modern high explosives very frequently contain nitro-derivatives of the aromatic compounds obtained from coal tar, especially the mono- di- and tri-nitro-derivatives of benzene, toluene, and naphthalene. The nitro-groups in these compounds contribute oxygen for the explosive reaction. The trinitro-compounds of substances containing only one benzene ring are explosives in themselves; trinitrotoluene, for instance. Trinitrotoluene is not only a constituent of composite explosives, but is also very largely used by itself as a charge for shell and submarine mines, and for other military and naval purposes, for which its insensitiveness combined with its great violence render it suitable. Picric acid (trinitrophenol) is also much used for these purposes, and trinitrocresol to a less extent. Although they detonate with great violence, these trinitro-compounds do not contain sufficient oxygen to oxidise the whole of the carbon they contain even to the stage of carbon monoxide. Their power as explosives is, therefore, increased by mixing them with oxygen carriers. Commercial explosives containing trinitrotoluene always have also some other constituent which can supply the deficient oxygen.

NITRIC ESTERS.—Nitroglycerin and the nitro-celluloses are the principal members of another very important group of substances that can be used as explosives without admixture. Strictly speaking, they are not nitro-derivatives, but nitric esters. The more highly nitrated celluloses, such as guncotton, contain enough oxygen to convert all the hydrogen into water and the carbon into monoxide, and even some of it into dioxide. Nitroglycerin, $C_3H_5N_3O_9$, not only has enough to oxidise entirely all its hydrogen and carbon, but also has a little oxygen left over. Nitroglycerin is the most powerful explosive compound known, but its power is increased by dissolving in it a small proportion of nitrocellulose, which utilises the excess of oxygen and at the same time converts it into a gelatinous solid known as blasting gelatin.

SMOKELESS POWDERS.—All smokeless powders consist largely of nitrocellulose, which has been more or less gelatinised and converted into a compact colloid by means of a suitable solvent; many of them contain practically nothing else, but in others there is a considerable proportion of nitroglycerin. Small percentages of mineral jelly, inorganic nitrates, and other substances are also added, in many cases to improve the ballistics or the stability. Powders for rifled arms are always colloided as completely as possible, whether they be for small-arms or ordnance, to make them burn slowly and regularly, but in shot-gun powders the original structure of the nitrocellulose is not always destroyed entirely, as they are required to burn comparatively rapidly.

ENDOTHERMIC COMPOUNDS.—There are some explosive compounds which do not depend at all for their action on oxidation or reduction. These are endothermic substances, which decompose with the evolution of gas and heat; they are usually rather sensitive. The only compounds of this class that are of commercial importance are fulminate of mercury, $Hg(CNO)_2$, and lead azide, PbN_4 , both of which are used only for exploding other explosives.

VELOCITY OF EXPLOSION.—The heat and gas evolved are the two principal factors which govern the power of an explosive, *i.e.* the amount of work it can do in the way of displacing objects. But the time taken by the explosion is also a matter of great importance. The rate of explosion is measured by making a column of the explosive, confining it, if necessary, in a metal

tube, and measuring the time that the explosive wave takes to travel a known distance. In black powder and similar nitrate mixtures the velocity of explosion is only a few hundred metres a second, but with modern high explosives the velocity of detonation is from two to seven thousand metres a second. This naturally makes them much more violent and destructive. Explosives of the gunpowder type are used when earth or soft rock is to be blasted, or when the material must not be broken up too much. Propellants for use in firearms are required to burn slowly; for rifled arms they must be slower even than gunpowder. They are not exploded by means of another high explosive, but merely lit by a powerful flame, and should then burn by concentric layers. The rate of burning increases with the pressure in the gun, but for completely gelatinised powders it is less than a metre a second. A. MARSHALL.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE Scottish Association for the Medical Education of Women has placed with the authorities of the University of Edinburgh the sum of 237*l.* for the purpose of founding a prize for women medical students.

THE Foulis memorial scholarship of the University of Glasgow has been awarded to Dr. John Cruickshank, pathologist to the Crichton Royal Institution, Dumfries, for distinction in original work in pathology.

It is announced in the issue of *Science* for January 14 that four business men of Portland have contributed 500*l.* toward the new buildings for the medical department of the University of Oregon, Portland. This makes available the 10,000*l.* appropriated by the State. The officers of the college now propose to raise an additional 20,000*l.*

THE issue of the *Pioneer Mail* for January 1 contains a report of the eleventh session of the Indian Industrial Conference, which commenced its sittings on December 24 last. It was the first time the conference had met in Bombay since its inception. There was an unusually large attendance of delegates and distinguished visitors. The president, Sir Dorabji J. Tata, is one of the pioneers of Indian industry. In the course of his address, he referred to the importance of industrial education, and said industrial education in the widest sense of the term is primarily the function of the State. But a good many people wish the State to go far beyond this rôle and to enter into the actual field of industrial enterprise. The president's message to the Congress, and through it to his countrymen, was "Educate, Organise, Co-operate." Scientific, technical, economic education is the function of the State, but he said they must take their share of the burden. If they really wanted higher scientific education and were determined to profit by it, they would get it. Dr. H. H. Mann, principal of the Agricultural College, moved a resolution earnestly recommending the establishment of a technological faculty at the principal Indian universities, the development of already existing technical institutions, the opening of new institutions, and the gradual introduction of technical instruction in primary and secondary schools. The resolution, which was adopted, appealed to men of capital and industry to help young Indians technically trained in finding practical work and employment.

THERE is a widespread opinion among competent authorities that an independent inquiry should be made into our system of education, particularly as regards its organisation, the powers of the Board of Education, the relations of the Board to local education