(9·6) and 48 (9·1), the following are the observed magnitudes of the variable :—

1900. Jan.	16	...	8·8
	19	...	8·7
Feb.	20	...	9·0
March	14	...	9·5

SOLAR ECLIPSES OF THE 20TH CENTURY.—In a reprint from the *Bulletin de la Société Astronomique de France* for November, M. Camille Flammarion brings together the local particulars for the eclipses of the sun which will be visible in Paris during the 20th century. Forty-three eclipses will be visible, but only thirty-three under good observing conditions. Special attention is drawn to the eclipses of April 17, 1912, and August 11, 1999, as although Paris is not included in the path of totality, in each case the central line of eclipse is only a short distance away from the capital. Maps are given of the paths of the shadow for both dates. These are also reproduced in the last number of the *Bulletin* (March).

A BRILLIANT FIREBALL.—On March 28, 8h. 31m., a very large meteor, giving several flashes like vivid lightning, was observed from the south-eastern parts of England. At Bishops Stortford, Herts, the light was so great that it illuminated the country, and three distinct explosions were observed. A sound like that of the roar of a distant cannon followed the disappearance of the meteor, and would indicate that it was 24 miles distant, but this is probably much underestimated. The meteor descended from the constellation Leo in the south. In Berkshire it was seen falling in Virgo, and it flashed out very brilliantly just prior to its disruption. The head of the meteor was very much brighter than Venus, and it travelled rather swiftly. Two vivid flashes were observed here as at Reading, where the terminal point of the flight was noted as being near ε Virginis. At the latter place the phenomenon ended in a cloud of sparks, and for a moment the sky and landscape were flooded in light. At Blackheath the meteor was seen by Mr. Crommelin, of the Greenwich Observatory. He estimated it as three times as brilliant as Venus at her brightest, and describes the terminal point as 1° N. of β Leonis. Many reports of this brilliant object are available for discussion, and it will be possible to determine its real path satisfactorily. Many large fireballs are directed in very slow flights from westerly radiants, but in this case the object moved swiftly, and probably had a radiant not far from the star ε in Ursa Major. Its position was over the east coast of Kent, and its height, when it finally burst and disappeared, about 52 miles.

MODERN EXPLOSIVES. [1]

THE subject of explosives is one which never fails to excite interest even under the most ordinary conditions, doubtless owing to the enormous potentiality of these substances, whilst at the present time more than usual attention is directed to them, it being scarcely possible to read a daily paper without finding some reference to the behaviour of various modern explosives in the theatre of war.

Explosion may be defined as chemical action causing extremely rapid formation of a very great volume of highly expanded gas, this large volume of gas being generally due to the direct liberation by chemical action and the further enormous expansion by the heat generated. Explosion itself may therefore be regarded as extremely rapid combustion, whilst the effect is obtained by the enormous pressure produced owing to the products of combustion occupying probably many thousand times the volume of the original body. The effect of high temperature is seen in the well-known case of explosion of a mixture of hydrogen and oxygen, where if the original mixture and the products of explosion are each measured at the same temperature above the boiling point of water, a less volume of gas (water vapour) is actually found. The explosion can only have been produced by the enormous expansion of this vapour in the first place by the heat of the reaction. Such an explosion when carried out in a closed bomb with the mixed gases under ordinary conditions of measurement produces a pressure of about 240 lbs. to the square inch. A more practical illustration is seen with nitroglycerine, which Nobel found yielded about 1200 times its own volume of gas calculated at

[1] A lecture delivered at the London Institution on February 12, by Mr. J. S. S. Brame.

ordinary temperatures and pressures, whilst the heat liberated expands the gas to nearly eight times this volume.

Clearly, then, a substance for use as an explosive must be capable of undergoing rapid decomposition or combination with the production of large volumes of gas, and further produce sufficient heat to greatly expand these gases ; the ratio of the volume of gases at the moment of explosion to the volume of the original body largely determining the efficiency of the explosive.

Explosives may be divided into two great classes—mechanical mixtures and chemical compounds. In the former the combustible substances are intimately mixed with some oxygen-supplying material, as in the case of gunpowder, where carbon and sulphur are intimately mixed with potassium nitrate ; while gun-cotton and nitroglycerine are examples of the latter class, where each molecule of the substance contains the necessary oxygen for the oxidation of the carbon and hydrogen present, the oxygen being in feeble combination with nitrogen. Many explosives are, however, mechanical mixtures of compounds which are themselves explosive, *e.g.* cordite, which is mainly composed of gun-cotton and nitroglycerine.

Two methods are in common use for bringing about explosions—ignition by heat, thus bringing about ordinary but rapid combustion, molecule after molecule undergoing decomposition ; and detonation, where the effect is infinitely more rapid than in the first case ; in fact, it may be regarded as practically instantaneous. The result may be looked upon as brought about by an initial shock imparted to the explosive by a substance—the detonating material—which is capable of starting decomposition in the adjacent layers of the explosive, thus causing a shock to the next layer and so on with infinite rapidity. That the results are not entirely due to the mechanical energy of the liberated gas particles is shown by the fact that the most powerful explosive is not the most powerful detonator ; neither is it entirely due to heat, since wet substances undergo detonation. The probability is that the result is brought about by vibrations of particular velocity which vary for different substances, the decomposition being caused by the conversion of the mechanical force into heat in the explosive, thus bringing about a change in the atomic arrangement of the molecule. According to Sir Frederick Abel's theory of detonation, the vibrations caused by the firing of the detonator are capable of setting up similar vibrations in the explosive, thus determining its almost instantaneous decomposition.

The most common and familiar of explosives is undoubtedly gunpowder, and although for military purposes it has been largely super-eded by smokeless powders, yet it has played such an important part in the history of the world during the last few centuries that apart from military uses it is even now of sufficient importance to demand more than a passing notice.

Its origin, although somewhat obscure, was in all probability with the Chinese. Roger Bacon and Berthold Schwartz appear to have rediscovered it in the latter years of the thirteenth and earlier part of the fourteenth centuries. It was undoubtedly used at the battle of Crecy. The mixture then adopted appears to have consisted of equal parts of the three ingredients—sulphur, charcoal and nitre ; but some time later the proportions, even now taken for all ordinary purposes, were introduced, namely—

Potassium nitrate...	...	...	...	75	parts
Charcoal ...	...	...	...	15	,,
Sulphur ...	...	...	...	10	,,
				100	,,

Since gunpowder is a mechanical mixture, it is clear that the first aim of the maker must be to obtain perfect incorporation, and necessarily in order to obtain this, the materials must be in a very finely divided state. Moreover, in order that uniformity of effect may be obtained, purity of the original substances, the percentage of moisture present, and the density of the finished powder are of importance.

The weighed quantities of the ingredients are first mixed in gun-metal or copper drums, having blades in the interior capable of working in the opposite direction to that in which the drum itself is travelling. After passing through a sieve, the mixture (green charge) is passed on to the incorporating mills, where it is thoroughly ground under heavy metal rollers, a small quantity of water being added to prevent dust and facilitating incorporation, and during this process the risk of explosion is greater possibly

than at any other stage in the manufacture. There are usually six mills working in the same building, with partitions between. Over the bed of each mill is a horizontal board, the "flash board," which is connected with a tank of water overhead, the arrangement being such that the upsetting of one tank discharges the contents of the other tanks on to the corresponding mill beds below, so that in the event of an accident the charge is drowned in each case. The "mill-cake" is now broken down between rollers, the "meal" produced being placed in strong oak boxes and subjected to hydraulic pressure, thus increasing its density and hardness, at the same time bringing the ingredients into more intimate contact. After once more breaking down the material (press-cake), the powder only requires special treatment to adapt it for the various purposes for which it is intended.

Within the last half-century an enormous alteration has taken place in artillery, the old smooth-bore cannon, firing a round shot, having gradually given place to heavy rifled cannon, firing cylindrical projectiles and requiring very large powder charges. This has naturally had its influence on the powder used, and modifications have been introduced in two directions—first, alteration in the form of powder, and second, in the proportions of the ingredients. As the heavier guns were introduced, a large grain powder which burned more slowly was adopted, but further increase in the size of the guns led to the introduction of pebble powders, which in some cases consisted of cubes of over an inch side. Such cubes having large available surface evolved the usual gases in greater quantity at the start of the combustion than towards the finish, since the surface became gradually smaller, thus causing extra strain on the gun as the projectile was only just beginning to move. General Rodman, an American officer, introduced prism powder to overcome this difficulty, the charges being built up of perforated hexagonal prisms in which combustion started in the perforations and proceeding, exposed more surface, the prisms finally breaking down into what was virtually a pebble powder.

In order to secure still further control over the pressure, modifications in the proportions of the ingredients became necessary ; the diminution of the sulphur and increase of the charcoal causing slower combustion, and moreover the use of charcoal prepared at a low temperature giving the so-called "cocoa-powders."

The products of the combustion of powder and its manner of burning are largely influenced by the pressure, a property well illustrated by the failure of a red-hot platinum wire to ignite a mass of powder in a vacuum, only a few grains actually in contact with the platinum undergoing combustion. The gaseous products obtained are carbon dioxide, carbon monoxide and nitrogen, other products being potassium carbonate, sulphate and sulphide. The calculated gas yield at $0°$ C. and 760 mm. pressure is 264.6 c.c., whilst Noble and Abel actually obtained by experiment 263.74 c.c., numbers agreeing very closely. At the temperature of explosion this volume is enormously increased.

In 1832, Braconnot found that starch, ligneous fibre and similar substances when treated with strong nitric acid yielded exceedingly combustible substances, and Pelouze in 1838 extended the investigation to cotton and paper. Schönbein announced in 1845 his ability to make an explosive which he termed gun-cotton, and a year later Böttger made a similar announcement, and on a conference being held between these chemists their methods were found to be identical. The method was not disclosed at the time, since it was hoped that the German Government would purchase the secret, but in a very short time several investigators solved the problem, and attempts to make the new explosive commercially were common. Unfortunately the earlier product was unstable, and several disastrous accidents occurred which led to the abandonment of the experiments except in Austria. General von Lenk, who continued experimenting in that country, showed that if sufficient care was taken to ensure complete nitration and to remove all traces of free acid from the finished material, the substance was stable. He introduced a method of manufacture which was improved by Sir Frederick Abel in 1865. The physical character of the cotton fibre is such that it presents every obstacle to the removal of free acid, since it is built up of capillaries, but by reducing these tubes to the shortest possible length, as in Abel's process, the removal of acid is facilitated.

Since water is a product of the reaction of nitric acid on cellulose, the nitric acid would become diluted, forming "collodion cotton" instead of the more highly nitrated gun-cotton,

and therefore sulphuric acid is used with the nitric acid to absorb this water, the usual proportions being three parts by weight of sulphuric acid (1.84) to one part by weight of nitric acid (1.52). Cotton waste, which has been picked, cleaned, cut into short lengths and dried, is dipped in $1\frac{1}{4}$ lb. charges in the acid, removed after five or six minutes, the excess of acid squeezed out, and the cotton placed in cooled earthenware pots for some twenty-four hours for nitration to be completed. The gun-cotton now goes through the lengthy process for removal of all traces of acid, starting with the removal of the greater portion of the acid by a centrifugal extractor, washing in water till no acid taste can be detected, boiling in water till free from action on litmus, reducing to pulp in a hollander, and, finally, the thorough washing of the pulp by more water. If the product now satisfies the tests for purity, sufficient alkali—lime-water, whiting and caustic soda—is added to leave from one to two per cent. in the finished gun-cotton. The pulp is drawn up into a vessel from which it can be run off in measured quantities into moulds fitted with perforated bottoms, the water being drawn off by suction from below, and, finally, a low hydraulic pressure is brought to bear on the semi-solid mass. The blocks are taken to the press-house and submitted to a pressure of some five tons per square inch, after which the finished block will contain from twelve to sixteen per cent. of water.

From its chemical reactions gun-cotton must be regarded as an ether of nitric acid, a view first suggested by Béchamp. The point of ignition of the substance has been found to vary considerably, ranging from $136°$ to $223°$ C., this difference being probably due to variations in composition. Good gun-cotton usually ignites between $180°$ and $184°$C. The combustion is extremely rapid when fired in loose unconfined masses, so rapid, in fact, that it may be ignited on a heap of gunpowder without affecting the latter. When struck between hard surfaces gun-cotton detonates, but usually only in that portion which is subjected to the blow. The volume of permanent gases evolved by the explosion of gun-cotton, as stated by different observers, has varied greatly. Macnab and Ristori give for nitrocellulose —13.30 per cent. nitrogen—673 c.c. per gram, calculated at $0°$ C. and 760 mm. Berthelot estimates the pressure developed by the detonation of gun-cotton—sp. gr. 1.1—under constant volume as 24,000 atmospheres or 160 tons per square inch.

Various attempts have been made to adapt gun-cotton for use in guns, but the tendency to create undue pressure led to its abandonment. In 1868, Mr. E. O. Brown, of Woolwich, showed that wet gun-cotton could be detonated by the use of a small charge of dry gun-cotton with a fulminate detonator, and since it can be stored and used in the moist state, it becomes one of the safest explosives for use in submarine mines, torpedoes, &c.

Nitroglycerine is a substance of a similar chemical nature to nitrocellulose, the principles of its formation and purification being very similar, only in this case the materials and product are liquids, this rendering the operations of manufacture and washing much less difficult. The glycerine is sprayed into the acid mixture by compressed air injectors, care being taken that the temperature during nitration does not rise above $30°$ C. The nitroglycerine formed readily separates from the mixed acids, and being insoluble in cold water, the washing is comparatively simple.

This explosive was discovered by Sobrero in 1847. Nitroglycerine is an oily liquid readily soluble in most organic solvents, but becomes solid at three or four degrees above the freezing point of water, and in this condition is less sensitive. It detonates when heated to $257°$ C., or by a sudden blow, yielding carbon dioxide, oxygen, nitrogen and water. Being a fluid under ordinary conditions, its uses as an explosive were limited, and Nobel conceived the idea of mixing it with other substances which would act as absorbents, first using charcoal and afterwards an infusorial earth, "kieselguhr," and obtaining what he termed "dynamite."

In 1875, Mr. Alfred Nobel found that "collodion cotton"—soluble gun-cotton—could be converted by treatment with nitroglycerine into a jelly-like mass which was more trustworthy in action than the components alone, and from its nature the substance was christened "blasting gelatine." The discovery is of importance, for it was undoubtedly the stepping-stone from which the well-known explosives ballistite, filite and cordite were reached. In 1888, Nobel took out a patent for a smokeless powder for use in guns, in which these ingredients were adopted

with or without the use of retarding agents. The powders of this class are ballistite and filite, the former being in sheets, the latter in threads. Originally camphor was introduced, but its use has been abandoned, a small quantity of aniline taking its place.

Sir Frederick Abel and Prof. Dewar patented in 1889 the use of trinitrocellulose and nitroglycerine, for although, as is well-known, this form of nitrocellulose is not soluble in nitroglycerine, yet by dissolving the bodies in a mutual solvent, perfect incorporation can be attained. Acetone is the solvent used in the preparation of " cordite," and for all ammunition except blank charges a certain proportion of vaseline is also added. The combustion of the powder without vaseline gives products so free from solid or liquid substances that excessive friction of the projectile in the gun causes rapid wearing of the rifling, and it is chiefly to overcome this that the vaseline is introduced, for on explosion a thin film of solid matter is deposited in the gun, and acts as a lubricant.

The proportion of the ingredients are :—

Nitroglycerine	...	...	...	...	58 parts.
Gun-cotton	...	...	...	...	37 ,,
Vaseline	...	..	...	...	5 ,,

Gun-cotton to be used for cordite is prepared as previously described, but the alkali is omitted, and the mass is not submitted to great pressure, to avoid making it so dense that ready absorption of nitroglycerine would not take place. The nitroglycerine is poured over the dried gun-cotton and first well mixed by hand, afterwards in a kneading machine with the requisite quantity of acetone for $3\frac{1}{2}$ hours. A water jacket is provided, since on mixing the temperature rises. The vaseline is now added, and the kneading continued for a similar period. The cordite paste is first subjected to a preliminary pressing, and is finally forced through a hole of the proper size in a plate either by hand or by hydraulic pressure. The smaller sizes are wound on drums, whilst the larger cordite is cut off in suitable lengths, the drums and cut material being dried at 100° F., thus driving off the remainder of the acetone.

Cordite varies from yellow to dark brown in colour according to its thickness. When ignited it burns with a strong flame, which may be extinguished by a vigorous puff of air. Macnab and Ristori give the yield of permanent gases from English cordite as 647 c.c., containing a much higher per cent. of carbon monoxide than the gases evolved from the old form of powder. Sir Andrew Noble failed in attempts to detonate the substance, and a rifle bullet fired into the mass only caused it to burn quietly.

Lyddite is probably the explosive which has received most notice during the past few months. In 1873, Sprengel, in a paper read before the Chemical Society, stated that " picric acid alone contains a sufficient amount of oxygen to render it, without the help of foreign oxidisers, a powerful explosive when fired with a detonator. Its explosion is almost unaccompanied by smoke."

Picric acid was first prepared by Hausmann in 1878, by treating indigo with nitric acid. It may be made by the direct nitration of phenol (carbolic acid), but a better result is obtained by first dissolving the phenol in sulphuric acid, forming phenol sulphonic acid, which is dissolved in water, and nitrating this compound with nitric acid (1·4). On cooling, the picric acid separates out, and is purified by recrystallisation from hot water, the yellow crystalline product being dried at a temperature not exceeding 100° C.

Picric acid containing as much as 17 per cent. of water can be detonated by a charge of dry picric powder ; a thin layer may also be exploded by a blow between metal surfaces, its sensitiveness to shock being greatly increased by warming, for at a temperature just below its melting point a pound weight falling from a height of 14 inches will explode it.

The sensitiveness of picric acid can be reduced by converting the powder into larger masses, this being accomplished either by granulating it with a solution of collodion cotton in ether-alcohol, as in the earlier forms of mélinite, or by fusion, which takes place some twenty degrees above the boiling point of water, and casting directly into the shell, as in lyddite and possibly the mélinite of the present day. In any condition perfect detonation would yield only colourless gaseous products rich in carbon monoxide, but the bursting of a lyddite shell is frequently accompanied by a yellow smoke, probably formed by undecomposed acid in the form of vapour. The shells appear to burst in two distinct ways, in one case giving a sharp powerful explosion with enormous concussion and no yellow smoke, and the other a dull heavy report with the yellow smoke, the two results appearing to be due to perfect decomposition in the first instance, whilst in the second partial decomposition only probably occurs.

Various mixtures of picric acid or its salts, together with some oxidising agent, have been used from time to time, Abel's powder consisting of ammonium picrate, potassium nitrate, and a small quantity of charcoal.

It is impossible to deal with the numerous other explosives which are largely in use in such a survey as this, and therefore attention has been confined to those which play the most active part in modern warfare.

ANTI-PLAGUE INOCULATIONS.

THE final proof of Chapter iv. of the Indian Plague Commission Report, dealing with Haffkine's anti-plague inoculations, has already been briefly referred to (p. 422) ; the following are further notes upon its contents :—

The first paragraphs contain a brief review of the history of preventive inoculation, the Commissioners trace it up to Haffkine's anti-cholera inoculations, in which a measured quantity of bacteria of known virulence was used. The next practical extension is stated to be the anti-typhoid inoculations introduced by one of the Commissioners (Prof. Wright), in which dead cultures were used ; the first of these inoculations were done in July and August 1896. Next, they say, come in chronological order the experiments of Yersin, Calmette and Borrel, conjointly in 1895, which showed it was possible to confer a certain amount of immunity against plague by injection of dead cultures of plague bacilli. Mr. Haffkine's anti-plague inoculations, the Commissioners say, represent an extension of this system of preventive inoculation to men. That Mr. Haffkine was not indebted to Yersin, Calmette and Borrel, nor to the system of anti-typhoid inoculation, for the suggestion to use dead cultures in his plague prophylactic, is evident from the words used by Mr. Haffkine in his lecture on " Anti-Cholera Inoculation " reported in the *British Medical Journal*, February 11, 1893 : " The microbes introduced under the skin do not propagate, but after a certain time they die and disappear. It is the substances which they contain, and which are set free when they die, that act upon the animal organism and confer immunity upon it. It is found that the same result can be obtained if the microbes be killed before inoculation, and if their dead bodies only be injected." Prof. Wright recognises this, for, in his account of the first anti-typhoid inoculations, *Lancet*, September 19, 1896, he says : " I need hardly point out that these anti-cholera inoculations have served as a pattern for the typhoid vaccinations detailed above."

Had the Commissioners quoted Mr. Haffkine's experiments with sterilised cultures of cholera bacilli, the anti-typhoid vaccine and the anti-plague prophylactic of Yersin, Calmette and Borrel, would have been shown to be an extension of Haffkine's own anti-cholera vaccine rather than the other way about, as it would appear from the report.

The report goes on to a very stringent criticism of the method of preparing the prophylactic. A certain proportion of bottles were found to be contaminated. In dealing with large quantities of prophylactic, it is not unlikely that some bottles should become contaminated, possibly by some of the corks not being sterile, as Mr. Haffkine suggests. The fact was not brought before the notice of Mr. Haffkine, but was sprung upon the Commissioners and mentioned in the daily Press at the time, with the evident intent to detract from the value of the prophylactic. The Commissioners investigated the matter, but found no serious results could be traced to such accidental contaminations.

The comparative value of the bacterial sediment and of the supernatant fluid is discussed, and, finally, the method of standardisation.

The process of manufacture is criticised from the point of view of scientific manipulation in a properly equipped laboratory for experiments on a small scale. The Commissioners do not mention the fact that the prophylactic is made on a large scale, as much as 20,000 doses being turned out per day, and this in a laboratory with no proper equipment, and with an insufficient and partially inefficient staff. And now having adversely criticised the theory and methods of the General who is conducting