of liquid nitrogen or air. Further, analogy leads us to the conclusion that the specific heat of liquid hydrogen is very much greater than that of liquid nitrogen or air. The combined result must therefore be that, if practically only 30 per cent., as above described, of liquid nitrogen or air can be collected, a very much smaller amount of hydrogen, say from 1 to 5 per cent., is all we can anticipate as the yield by similar methods of manipulation. Assuming that we had such a liquid, its use as a cooling agent would indeed be very expensive, since its cost may be taken as at least twenty times the cost of liquid air. One thing, however, can be proved by the use of the gaseous mixture of hydrogen and nitrogen, viz., that by subjecting it to high compression at a temperature of minus 200°, and expanding the resulting liquid into air, a much lower temperature than anything that has been recorded up to the present time can be reached. This is proved by the fact that such a mixed gas gives, under these conditions, a paste or jelly of solid nitrogen, evidently giving off hydrogen, because the gas coming off burns fiercely. Even when hydrogen containing only some 2 to 5 percent. of air is similarly treated, the result is a white solid material (solid air) along with a clear liquid of low density which is so exceedingly volatile that no known device for collecting it has been successful. To attain such a result it is necessary to liquefy and expand more than one pound weight (or about seven cubic yards) of hydrogen gas. Knowing the difficulties, from having to deal in the liquid state with the accumulated small impurities in such large amounts of gas, Prof. Dewar will not declare that he has had pure liquid hydrogen in one of his vacuum vessels, although what this liquid can be except hydrogen it is impossible to say.

The future progress of these costly and difficult experiments must depend very much upon questions of outlay, and it is to be hoped that the public will not assume that the endowment so handsomely given to the Royal Institution by Mr. Ludwig Mond for the maintenance of a public laboratory of research, to be called the Davy Faraday Laboratory, can be used for the prosecution of such investigations.

SYMPATHETIC EXPLOSIONS.

By C. A. MITCHELL, B.A. Oxon.

IN an explosion we have the sudden evolution of large quantities of gas which meet with external resistance. Thus, in the case of dynamite, the substance is suddenly decomposed into gases, which meet with the resistance offered by the surface of the earth on the one side and with that opposed by the weight of the atmosphere on the other.

Explosive agents are roughly classified as "high" and "low" explosives, the former term being usually applied to those exploded by detonators and used as destructive agents rather than for the propulsion of projectiles. Nitroglycerine and gunpowder may be taken as representatives of the two classes.

Substances liable to explosion are, as it were, in a state of unstable equilibrium, and often a slight cause is sufficient to so disturb that equilibrium that a fresh arrangement of the particles takes place—in other words, an explosion. A somewhat analogous instance of instability is to be noticed in the case of water cooled slowly below its freezing point without solidifying, as occasionally happens in bedroom jugs. When the jug is lifted the movement destroys the equilibrium and the water suddenly becomes ice. Prince Rupert's drops illustrate the same phenomenon. These are small pear-shaped globules prepared by allowing molten glass to fall from a short distance into cold water, which causes the exterior to cool more rapidly than the interior, and the mass is left in such a state of tension that, if the extreme tip of the drop be broken off with pliers, the whole flies to powder.

Explosive bodies differ very considerably in stability. The so-called iodide of nitrogen, a black powder formed by digesting iodine in a solution of ammonia, explodes when dry with the slightest touch. Nitroglycerine is more stable and requires the blow of a hammer for its explosion. This substance is prepared by allowing strong nitric and sulphuric acids to act upon glycerine, care being taken to keep the temperature low. It is an oily liquid and is very poisonous. As an explosive it is uncertain, and has been the cause of many accidents. When mixed, however, with an inert substance, such as sawdust, it is much more stable. This is the principle made use of in the manufacture of dynamite, which consists of nitroglycerine absorbed by a porous siliceous earth called kieselguhr.

Dynamite is very stable under ordinary conditions, as was well shown in the experiments carried out in the Lauenburg Fabrik in 1876.* A barrel containing 540 kilogrammes† was dropped a distance of 20 feet on to a paved road, and in a second experiment a weight of 10 kilogrammes was dropped on to a dynamite cartridge. In neither instance was there any explosion. The dynamite used burned quietly when thrown on a fire, but exploded powerfully even on an open surface when a detonating cartridge was exploded in contact with it. We have thus the curious phenomenon of a substance which burns quietly and withstands a heavy blow, but which disintegrates readily when another less stable body is exploded beside it. This is explained by the theory of an explosive wave which is communicated from the one explosive to the other. Where an explosive burns quietly there is much slower decomposition, and the particles first taking fire radiate their heat too quickly for the entire mass to be simultaneously raised to the temperature of explosion. If the heat cannot be dissipated sufficiently fast, as in the case of confined gun cotton, an explosion follows just as when a detonator is used. Thus the unstable equilibrium may be disturbed either by heat or by communication of a mechanical vibration. This latter method of sympathetic explosion, as it has been termed, is now very generally used to effect explosion of charges of dynamite and gun cotton.

That the deflagration of one substance can produce a sympathetic explosion at a distance has been illustrated by many accidents. The explosion of a quantity of nitroglycerine in one shed has often caused the explosion of other materials some distance away. A remarkable instance occurred in 1888, in a factory at

Wandsworth, where the caps for toy pistols were made. It was believed that the explosion was owing to one of these amorces, containing more than the regulation amount of composition, having been cut with scissors, and thus causing all the rest to explode. The shed was wrecked, and three girls lost their lives. A similar case happened in France, where a child was killed by cutting open a cap, which caused two large packets to explode.

When an explosion is communicated from one cartridge to another, there is a gradually weakening effect. This was proved experimentally in 1872, by Captain Muntz, at Versailles. The explosion of the first charge excavated a funnel-shaped hole in the ground measuring 0.9 meter* in diameter. The shock caused a second similar cartridge placed at some distance to explode. But in this case the diameter of the hole excavated was only 0.66 meter.

Captain Colville found that there was a definite relation between the weight of the charge used and the distance between the cartridges. A charge weighing one kilogramme, and containing 75 per cent. of dynamite, communicated its explosion on hard ground 0.3 meter. Where D represents the distance in meters, and C the weight of the charge in kilogrammes, he showed that under these conditions $D = 3C$. When the cartridges were laid on a rail, the distance to which the explosion could be communicated was increased, and $D = 7C$. On the other hand, on soft or plowed earth, the distances were much less.

To explain this property of explosives, Sir Frederick Abel advanced the attractive theory of a sympathetic rhythmic vibration between the substance detonating and that detonated, analogous to the synchronous vibrations set up by sound waves. A certain note of a piano will often cause a glass to jingle, and if the glass be made to emit its note, it will be found to be the same as the note of the piano—that is, each vibrates at the same rate. Sir Frederick Abel thus expresses his theory: "Vibrations produced by particular explosions, if synchronous with those which would result from the explosion of a neighboring substance, will, by their tendency to develop those vibrations, either determine the explosion of that substance or at any rate greatly aid the disturbing effect of mechanical force suddenly applied."

Facts in support of this are that sometimes a feeble detonation will determine an explosion when a more violent one will not. Thus iodide of nitrogen will not cause compressed gun cotton to explode, nor does nitroglycerine cause the explosion of gun cotton in sheets on which is placed the case of nitroglycerine.

The interesting experiments of Champion and Pellet† tend, perhaps, to confirm this.

1. A very small quantity of iodide of nitrogen, detonated at one end of a long narrow tube, caused the explosion of a similar quantity of the same substance placed at the other end of the tube at a distance of seven meters. That the transmitted concussion was slight was shown by the insertion of a light pith ball in the middle of the tube.

2. Damp iodide of nitrogen was fixed to the strings of a bass viol. When it was dry the strings of a similar instrument were made to vibrate at a distance. A detonation occurred only when a note giving sixty vibrations per second was sounded. The G cord caused an explosion, while the E cord did not. The vibrations produced by metal plates acted in the same manner as strings.

From these results the observers came to the conclusion that explosion was due to vibratory motion independent of heat and shock.

This theory has not met with general acceptance.

Eissler‡ is strongly opposed to it. He urges that all the experiments of Champion and Pellet may be explained by taking into account the vibrations of the supports and the resulting friction. Moreover, the characteristic feature of a given note has never been established, but only the fact that below a certain rate of vibration the explosive effect ceases. He explains the facts by the supposition of two orders of waves, one explosive and the other purely mechanical.

In substantial agreement with him, Berthelot§ also objects to the theory of sympathetic vibrations. He proves that the chemical stability of matter is unaltered by merely sonorous vibrations, even when the substances experimented on are as unstable as ozone, which is so readily changed into oxygen. Therefore, according to him, sonorous waves cannot be the real agents in chemical decomposition and explosion. His explanation is that "explosive matter detonates, not because it transmits the vibratory energy by vibrating in unison, but, on the contrary, because it stops it and appropriates the energy." With reference to Abel's experiments, he argues that if gun cotton can explode nitroglycerine, why cannot nitroglycerine explode gun cotton, assuming that the two compounds vibrate in sympathy; whereas this transformation of energy into work may be readily explained by a difference in constitution.

The same chemist made a large number of experiments to determine the velocity of the explosive wave in the case of different explosives. Long, narrow tubes, made of lead, tin, or Britannia metal were used, and the rate of propagation of disturbance through the tube measured. He found this to depend on: (1) The diameter of the tube; (2) the density of the explosive; (3) the resistance of the material of the tube. The explosive wave from compressed gun cotton had a mean velocity of 5,200 meters per second in lead tubes, and of 6,000 meters per second in tin tubes. Liquid nitroglycerine gave results varying from 1,078 to 1,386 meters per second; while dynamite had a mean rate of 2,543 meters per second. It was found a matter of great difficulty to detonate the nitroglycerine in such narrow tubes. A curious feature was, that whether the tubes were curved or straight, the results obtained were substantially the same.—Knowledge.

APPARATUS FOR WEIGHING OUT LIQUIDS.

THE weighing out of liquids which readily volatilize, of fats and oils, of fuming acids, etc., is a lengthy and

inconvenient operation. The process is, however, much simplified by the use of the pipette shown in the figure. The exhaustion tube terminates in a capillary, which is bent within the bulb of the pipette toward the upper portions of its walls; the opposite side of the bulb is flattened in order that the pipette can be placed on the pan of the balance; the mouthpiece may be drawn out to a capillary, and the same applies to the discharge tube. A sufficient quantity of the liquid to be weighed is sucked up into the bulb so that the end of the capillary within the bulb projects be-

Fig. 1.

Fig. 2.

yond the surface of the liquid when the instrument is laid down on the flattened portion. After wiping the end of the tube, the pipette and its contents are weighed; the necessary quantity of liquid is then run out, and the weight redetermined. For weighing solid fats the instrument may be warmed; the error introduced by weighing a slightly warm liquid in a small pipette being for practical purposes quite negligible.—H. Schweitzer and E. Lungwitz, Chem. Zeit.

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* Ber. Dent. Chem. Ges., IX., 1802.

† A kilogramme = 2.2 lb.

* A meter = 39.3 inches.

† Comptes Rendus, LXXV.

‡ Modern High Explosives.

§ Les Matieres Explosives.

|| Comptes Rendus, 100, 314—320.