NITROGLYCERIN.

C TURE DELIVERED AT THE STEVENS INSTITUTE OF TECHNOLOGY, BY G. M. MOWBRAY, ESQ., OF NORTH ADAMS, MASS.

Thirty years ago the German chemist Schönbein discovered that iron behaved in a peculiar manner when immersed in a mixture of concentrated nitric and sulphuric acids. Instead of dissolving, it remained perfectly passive and unchanged. This led him to test his solution by putting some cotton in it. To his great surprise, the cotton did not dissolve either. He took it out again, squeezed it out, washed out all the acid, and put it in the drying apparatus in order to have it ready for analysis the next day. When he came back, his cotton was not there, and none of his students of whom he inquired had seen anything of it. He was convinced that somebody had been very careless, and repeated the experiment. This time, however, the Professor himself witnessed the disappearance of his cotton when the heat became sufficiently strong; and this showed him that a change had taken place in its structure. The new compound received the name of gun cotton, and the inventor took out a patent for it in 1846. Sir John Herschel spoke in the strongest terms of its great explosive power. At a meeting of the British Association, he said: "It might in the next generation arm mankind with the very wildest powers, by which they could tear up rocks, and almost call down lightning." Everybody began to make it, exhibit it at the dinner table, and discuss the question whether it was a true chemical compound or only a mechanical mixture formed by the retention of some of the acid in the pores of the cotton. The dispute was settled by Sobrero, a pupil of Pélouze and now Professor of Chemistry in the University of Turin. Walter Crum having shown that gun cotton, or pyroxylin, is a compound in which some of the hydrogen of the cotton is replaced by hyponitric acid, Sobrero made similar compounds with gum, sugar, dextrin, manna, and finally with glycerin, where it was evident that there could be no simple absorption. This was in 1848. Nothing further was heard of his invention of nitroglycerin until the Crimean war, when it was rumored that Admiral Napier was prevented from taking Cronstadt because he was afraid of torpedoes charged with the new terrible explosive by Professor Jacobs.

In 1864 the Swedish engineer Alfred Nobel obtained a patent for the application of nitroglycerin to blasting purposes. He found considerable difficulty in making it explode with certainty, and was obliged either to put gunpowder in the center of the nitroglycerin cartridge or nitroglycerin in the center of the gunpowder cartridge.

The lecturer next exhibited the properties of nitroglycerin. A slip of paper saturated with it was lighted, and burned with a light bluish flame; while another slip saturated with nitrobenzol, a similar compound, burned with a denser flame and gave off much dark smoke, showing the greater proportion of carbon in its composition. This nitrobenzol, from which artificial bitter almond flavoring is also made, is sometimes mixed with nitroglycerin in order to neutralize its explosive qualities and render it safe for transportation. It can then be exploded only by means of some powerful fulminate or by supplying it with oxygen through the addition of chlorate of potash.

A little nitroglycerin spread upon an anvil exploded with a loud report when struck with a hammer; nitroglycerin mixed with one third of nitrobenzol did not explode until chlorate of potash was added, and not then at the first trial.

The glycerin from which nitroglycerin made is so common a compound that it requires no description. It was first obtained as a residue in the manufacture of diachylon or lead plaster, obtained by boiling olive oil and litharge. It is perfectly soluble in water, and greedily absorbs moisture from the atmosphere; a tumbler nearly filled with glycerin will draw about $\frac{3}{8}$ of an inch of water from the air in a night. Nitroglycerin, on the contrary, is insoluble in water. When tasted or even touched with the hands, it produces a persistent throbbing headache; but the system soon becomes accustomed to it, and it then ceases to have any effect. Nitroglycerin is obtained by adding gradually $\frac{1}{2}$ lb. of glycerin to a mixture of 1 lb. of nitric acid and 2 lbs. of sulphuric acid. Various conditions enter into its manufacture, which cause the product to be more or less easily exploded. The result is glycerin in which one, two, or three equivalents of hydrogen are replaced by hyponitric acid.

The attention of the lecturer was first attracted to nitroglycerin in 1865, by several terrible explosions which it had caused. One occurred in New York city in Greenwich street, opposite the Wyoming Hotel. One of the guests of the hotel, on polishing his boots, had noticed a reddish vapor issuing from the box on which he rested his foot. The hotel clerk took the box outside and threw it into the gutter. An explosion instantly followed, by which every pane of glass within a hundred yards was shattered, pedestrians were thrown down, and the pavement broken up. It turned out that the box contained nitroglycerin, left by a guest as security for his board.

The next explosion was that of the steamer European, at Aspinwall, on the Isthmus of Panama. Forty-seven persons were killed, the vessel, the pier, and the warehouses near by were destroyed, and the damage was over a million dollars. Directly after this an explosion occurred in the express office of Wells, Fargo, & Co., corner of California and Montgomery streets, San Francisco. Eight persons lost their lives, and property to the amount of a quarter of a million dollars was destroyed.

Now here was a substance manufactured at Hamburgh, Germany; carted to the wharf; loaded on board of the steamer by stevedores; reshipped at London to Panama; a part of it forwarded across the Isthmus by railway; thence lightered to and loaded upon the steamer; bearing a twelve day's voyage to San Francisco, where it was taken to the express office; handled with the usual recklessness of expressmen, and yet it did not explode. These considerations led the lecturer to investigate the subject, after having maturely reflected on the question whether a man "who had a home ought to embark in so dangerous an enterprise," and having at one time concluded "that he had better keep a peanut stand" than have anything to do with nitroglycerin without thoroughly understanding its properties.

The following July (1867) the lecturer was sent for by the engineers of the Hoosac tunnel, who were desirous of finding some one who would take charge of the manufacture and use of nitroglycerin, and be responsible for it. He accepted the position on the condition of having absolute authority to employ and discharge all connected with the use of the explosive, and of managing the operation without interference from anybody.

A preliminary experiment with a charge of six ounces of nitroglycerin proved so powerful that those who heard the report thought his whole works had blown up. He then gave a very amusing account of his first entrance into the tunnel, carrying a pail filled with cartridges in one hand, his apparatus in the other, and the fuses on his person. All the miners were cleared out, and he proceeded to charge the holes, while the silence of the place was interrupted only by the plash of water trickling through the roof. When all the holes were filled, and the wires connecting them were ominously hanging out of the holes, resembling an exaggeration of rats' tails, a sense of anxiety and discomfort was unavoidable. Everything, however, went off satisfactorily, and the spark from the electric machine exploded all the cartridges. Until the men were drilled sufficiently to be safely entrusted with this business, the lecturer had to go in the tunnel every 8 hours, and 3 of the intervening hours were used up in preparing the charges. Five tuns of nitroglycerin were thus used per month; and for the same amount of rock blasted out, only 1 life was lost through nitroglycerin, where 30 or 40 were lost through gunpowder. It is safe to say that the Hoosac tunnel would never have been completed without nitroglycerin.

The lecturer then exhibited the electrical machine, contained in a neat keg. To this he connected 15 fuses and exploded them before the audience. The machine is a frictional one, its condenser having 450 inches of surface and the rubber being 6 by 8 inches. In practice, the fuses, instead of being close together as in the experiment, are attached to cartridges placed in holes from 6 to 12 feet apart, which they fill about two thirds or two fifths. As much as 6,000 cubic yards of solid rock have been blasted out at one discharge at Lake Champlain. The drill holes are made very deep, sometimes as deep as 50 feet. They are first gaged to make sure that they will receive the cartridges. Then the exploders are attached to the nitroglycerin cartridges, and these are immediately passed into the drill holes. The holes are next plugged with a bung, perforated to allow the delicate connecting wires to pass and to keep them away from the rock, by which the insulation would otherwise be destroyed. Finally, the wires are connected with the abovementioned electrical apparatus, which is kept in a warm, dry room, and the explosions take place the moment the apparatus is charged.

Owing to the many fatal accidents resulting from the handling of Nobel's impure, dark-colored nitroglycerin, the manufacturers were obliged to substitute a modification for it, to which they gave the name of dynamite. This dynamite consists of a mixture of nitroglycerin and a kind of silicious or infusorial earth, "known under the various names of silicious marl, tripoli, rottenstone, etc." This earth absorbs the nitroglycerin without destroying it, and the result is a mixture which is no longer liquid and which can be transported with greater safety. Dynamite is only one of a large number of similar compositions of nitroglycerin. Mixed with sponge or other vegetable fiber, nitroglycerin becomes *porifera nitroleum*; with plaster of Paris, selenitic powder; with red lead, metalline nitroleum; with gunpowder in a fine state of division, lithofracteur or rendrock; with sawdust, dualin. Dynamite, adulterated with nitrates of soda or potash, is sold as giant powder. These additions are manifestly adulterations, because they are converted into gases, so much more slowly than nitroglycerin that the power of the latter is considerably impaired. One might as well attempt to quicken the electric current by coupling it to the velocity of a locomotive. Give four men a weight to lift which requires the united force of all of them, the exertion of force by any one, later than that of the others, wastes the force of all.

Some of these compounds develop poisonous gases when they are exploded, and cannot therefore be used in tunnels without detriment to the workmen. In the Hoosac tunnel, when they were tried, the men would not pass through after the discharge until a train had re-established ventilation, but preferred to wait for several hours to go home.

Sometimes a diluted form of nitroglycerin is advantageous, provided its price is proportionate to that of the pure article. Where the rock is hard and tough, it is easier to bore holes an inch and a half than only an inch in diameter, because the drilling machine would soon batter up the thinner drill; on the other hand, a charge of nitroglycerin, diluted so as to fill up two thirds of the depth, would be much more effective than if it were concentrated at the bottom. This, of course, does not prove that these diluted compounds are stronger than pure nitroglycerin. At Hell Gate the trinitroglycerin was found to be six times as powerful as giant powder; and, as Professor Morton says, a mixture of $47\frac{1}{2}$ parts of infusorial earth and $52\frac{1}{2}$ parts of nitroglycerin cannot be coaxed to explode, and might be recommended as a good filling for fireproof safes.

There are several methods of estimating the power of explosive substances. According to the experiments by Nobel and Abel, if the gases developed by the explosion of 2·2 lbs. of gunpowder are confined in the volume of 61 cubic inches, they will exert a pressure of 6,400 atmospheres, and the explosion will disengage 705 calories. The experiments of Messrs. Roux and Sarran, of Paris, with nitroglycerin and gun cotton, gave 1,784 calories for the former and 1,123 for the latter. Hence, if the explosive force of gunpowder is taken as unity, that of nitroglycerin will be 2·53, and that of gun cotton 1·59.

M. Berthelot computes this force in a different manner. Taking 3,405 grains of nitroglycerin, he calculates that the elements composing it would produce an amount of heat equal to 430,500 calories, if they were transformed into water and carbonic acid: but the heat actually disengaged in making this quantity of nitroglycerin is 130,500 calories; hence the difference between the two figures, 300,000 calories, represents the total amount of heat which the 3,405 grains of nitroglycerin are still capable of developing. This makes 1,320 calories for each 15 grains.

There is one element which seems to have been ignored in these calculations, namely, the time in which an explosive is converted into gaseous matter. It takes a bullet one sixtieth of a second to reach the muzzle of a gun. A charge of gun cotton, in blasting a mine or in a rifle, explodes after the manner of gun cotton; but if fired by means of a suitable charge of fulminate of mercury, it goes off with extreme violence. Nitroglycerin soaked into blotting paper burns rapidly with a voluminous flame when lighted by flame, but detonates violently when spread on an anvil and struck with a hammer, or when fired by means of the initial explosion of a fulminate. Now, velocity of explosion is the very essence of disruptive force. This principle is lost sight of also in Mr. Nobel's method of testing explosives, which depends upon their projectile power. He puts them into a mortar and measures the distance to which they send a ball. Taking the ballistic force of nitroglycerin as 100, he finds for equal weights of other substances the following figures: Compressed guncotton, 71; dynamite (75 per cent nitroglycerin), 72; gunpowder with 20 per cent nitroglycerin, 50; fulminate of mercury, 30; strongest rend-rock, 50·5; Curtis and Harvey's powder (exploded with a fulminate), 28.

The mistake here is that substances like nitroglycerin, which, by their velocity of explosion, produce the best effect in blasting, are ill adapted to the propulsion of projectiles. They will burst the gun or expend part of their force in crushing the ball, and hence give indications much below their true strength. The real strength of nitroglycerin is probably 8 or 10 times that of gunpowder.

The explosion of nitroglycerin is so rapid and violent that the air above it has no time to move away, but acts like a solid; hence it will act downwards when placed upon the surface of a rock.

The lecturer, in the next place, put upon the table little heaps of dynamite, rend-rock, and mica powder, the latter being his own invention. He called attention to the fact that the mica powder burned with greater rapidity, and claimed that it was a more powerful explosive than the others. All the other compounds are made with a view to absorption of nitroglycerin by some inert substance; and when they are fired, there are two explosions, one of nitroglycerin on the outside of the particles of the infusorial earth, and another of that contained in the foraminiferous interstices. Hence there two weak blows instead of one strong one. In the mica powder, however, which consists of finely divided scales of mica, not more than $\frac{1}{4000}$ to $\frac{1}{1000}$ of an inch thick, moistened with nitroglycerin, there is no absorption, and the whole mass is exploded at once.

Mr. Mowbray then protested against the popular assumption that nitroglycerin cannot be prepared with sufficient purity to remain unchanged, to be safe to use, safe to transport, and safe to store. He has sent 1,000,000 lbs. of his pure limpid trinitroglycerin all over the country in teams, which jolted over rough roads, rolled down bluffs, and broke down; in trains which were thrown off the track; and in sloops which were storm-tossed.

He concluded by hoping that railroad and transportation companies would soon put an end to the clandestine transportation of nitroglycerin under feigned names, by appointing certain days for receiving it.

C. F. K.

Hydrocarbons in Dynamite.

A Rhenish manufacturer of dynamite mixes 2 or 3 per cent of some hydrocarbon, like naphthaline, with the nitroglycerin employed. Two different sorts of dynamite are made, in which the following proportions are employed:

	1st.	2d.
Infusorial earth	23	20
Chalk	2	3
Solution of naphthaline in nitroglycerin	75	70
Barytes		7
	100	100

A NEW printing ink is prepared by first dissolving iron in sulphuric, hydrochloric, or acetic acid. Half the solution is oxidized by means of nitric acid, after which the two halves are mixed, and precipitation is produced by oxide of iron. The precipitate is filtered, washed, and mixed with equal parts of tannic and gallic acid, which produces a black bordering on blue. The black is washed and dried, then mixed with linseed oil; and the ink obtained is suitable for either letterpress printing or lithography