

EXPLOSIVES

8/15/05

HISTORY

Roger Bacon described the preparation of the first explosive, black gunpowder, in 1249. By 1300, it was known and used throughout Europe. Written descriptions and drawings of guns appeared in documents as early as 1325, but the active period of gunpowder warfare was not initiated until the English used guns in the battle of Cressy in 1346. In 1788, Berthollet, a student of Lavoisier, prepared a chlorate gunpowder but abandoned its use following a disastrous explosion. In 1800, Edward Howard described the preparation and properties of mercury fulminate (the preparation has not changed essentially to this day), but it was not until 1864 that Alfred Nobel adopted it for use in percussion caps. The discovery by Nobel that an explosive wave from the firing of a percussion cap could initiate the explosion of another explosive has been called the most important discovery and invention in the history of the explosive art.

The history of modern explosives dates from the discovery of nitrocellulose (more correctly named cellulose nitrate) independently by Schonbein and Bottger in 1845. They soon perceived the military possibilities of their product and cooperated with each other to exploit a form of nitrocellulose called guncotton. Many disastrous explosions followed, both in the preparation and use of the explosive. These produced such unfavorable impressions that the manufacture of guncotton was discontinued in England, France, and Austria for many years.

Glyceryl trinitrate, or nitroglycerine as it is commonly called, was first prepared by Sobrero, an Italian physician and chemist in 1846 or early 1847. He noted that the material was a powerful vasodilator - "a trace of nitroglycerine placed upon the tongue -- gives rise to a most violent pulsating headache" - and prescribed it medicinally in the treatment of angina pectoris (a common heart disease), a use that has continued to this day. Sobrero cautioned that the material was highly explosive - "the residue of nitroglycerine was certainly not more than 2 or 3 centigrams. On heating the dish over a spirit lamp, a most violent explosion resulted, and the dish was broken to atoms." Sobrero did not pursue the use of nitroglycerine as an explosive until several years after the firm of Immanuel Nobel & Sons had developed a factory for its production. In 1859, one of the Nobel sons, Alfred, began experiments which led in 1864 to the invention of the blasting cap for initiating the explosion of nitroglycerine. Owing to its extreme sensitivity, pure nitroglycerine proved very difficult to handle. Alfred Nobel overcame this difficulty by absorbing the nitroglycerine in an inert porous absorbent powder such as diatomaceous earth. The resulting pasty solid, known as dynamite, was much less sensitive and safer to handle. For this, he was issued a patent in 1867. The application of explosives for non-military purposes may be said to stem from this discovery.

The nitrocellulose mentioned above is made by treating cotton linters or wood pulp with a mixture of nitric and sulfuric acids. The reaction product is not a pure substance but is composed of several nitric esters of cellulose. In 1884, Paul Vieille, a French physicist, found that when this nitrocellulose mixture was treated with a solution of equal parts of alcohol and ether, a stiff gel formed. This gel could be rolled into thin sheets or extruded through a die. Evaporation of most of the solvent left a tough horn-like colloidal material called *collodian*. This solid burned at a much slower rate than guncotton; it would *deflagrate* rather than detonate when fired in guns. It

was thus satisfactory for use as a propellant. This material, smokeless on explosion, was adopted by the French Minister of Armaments as their '*Poudre B*', the first smokeless powder. With only minor changes, this was the powder used by our Navy from about the time of the Spanish-American War until the later stages of World War II. All nations today use similar powders, consisting of gelatinized nitrocellulose, either by itself (single base powder) or mixed with nitroglycerine (double base powder) and other ingredients as propellants for guns and rockets.

Meanwhile various explosive compounds and mixtures suitable for use as bursting charges were formulated. Among them were picric acid, ammonium picrate (Explosive D), TNT, PETN, RDX, EDNA, amatol, baratol and others. (See chart at end of chapter). To a greater or lesser extent, all are important military explosives today.

NATURE OF EXPLOSIONS AND EXPLOSIVES

An *explosion* is the effect produced by extremely rapid evolution of gases, usually at a high temperature. An *explosive* is any material or device which, by the rapid release of its potential energy, is capable of producing an explosion. Explosives may be divided into three classes: mechanical, nuclear, and chemical. Only chemical explosives will be discussed in this chapter.

Explosives may be chemical compounds or mixtures. *Black powder* is an intimate mixture of 75 parts potassium nitrate, 15 parts charcoal and 10 parts sulfur, by weight (i.e., a mixture of combustible material with an oxidizing agent). Under certain conditions, it is possible to substitute a more powerful oxidizing agent such as potassium chlorate, for potassium nitrate. Chlorate powders, in general, although more powerful, are also more sensitive to shock.

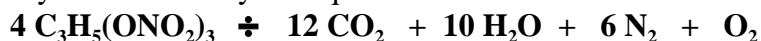
When black gunpowder is ignited, it reacts approximately as in the equation:



The products from explosions vary with conditions so any simple equation is an approximation.

A tremendous increase in volume, measured at one atmosphere, occurs due to the formation of nitrogen and carbon dioxide. Furthermore, the volume is greatly increased by the high temperature, which is about 2000 °C. For example, 270 grams of black powder, which occupy about 0.18 liters as a solid, expand to form 746 liters of gases measured at 2000 °C and 1 atm. - an expansion of 4150 times occurring in a fraction of a second. The K_2S is a solid and forms a smoke.

Nitroglycerine, $\text{C}_3\text{H}_5(\text{ONO}_2)_3$, is an example of an explosive chemical compound. When ignited, it reacts approximately as indicated by the equation:



All the products are gases at the temperature of the reaction. The conversion of 4 moles of explosive compound into 29 moles of gaseous product, at a very high temperature, generates the large pressure wave that is largely responsible for the destructive effects.

The reactions above show another notable feature of explosives. Atmospheric oxygen does not appear in these reactions, as would be required for simple combustion. Instead, explosives

typically have oxygen available *within the compound or mixture itself*. This is, in part, why explosive reactions can occur so rapidly. The extent to which an explosive can provide its own oxygen is described by the “oxygen balance”. Oxygen balance is computed from the following formula:

$$\text{Oxygen Balance} = \frac{-1600 (2x + (y/2) - z)}{\text{Molar Mass of Compound}}$$

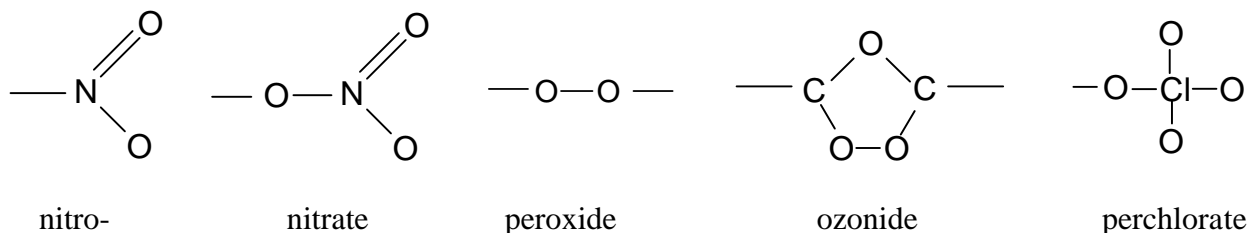
where:

- x = the number of atoms of carbon in the compound
- y = the number of atoms of hydrogen in the compound
- z = the number of atoms of oxygen in the compound

If an explosive molecule has within itself just enough oxygen to convert all of its carbon to carbon dioxide and all of its hydrogen to water, it is said to have *zero oxygen balance*; if the explosive molecule has insufficient oxygen within itself to convert all of its carbon and hydrogen to these products, it is said to have *negative oxygen balance*. In the case of nitroglycerine, the molecule has not only sufficient oxygen to convert all of its carbon and hydrogen to carbon dioxide and water, but has additional oxygen. This explosive is said to have a *positive oxygen balance*.

The ‘internal’ oxygen of an explosive compound is usually found in functional groups that are rich with that element. Most explosive compounds contain nitrogen, usually in *nitro* (-NO₂), *nitrate* (-ONO₂), or *nitramine* (-N-NO₂) groups and less frequently in *azide* (-N₃) and other groups. A few explosive compounds contain no nitrogen but are characterized by strong oxidizing agents such as *peroxide* (-OO-), *ozonide* (C-(OO)(O)-C-), or *perchlorate* (ClO₄) groups.

Common Functional Groups in Explosive Compounds

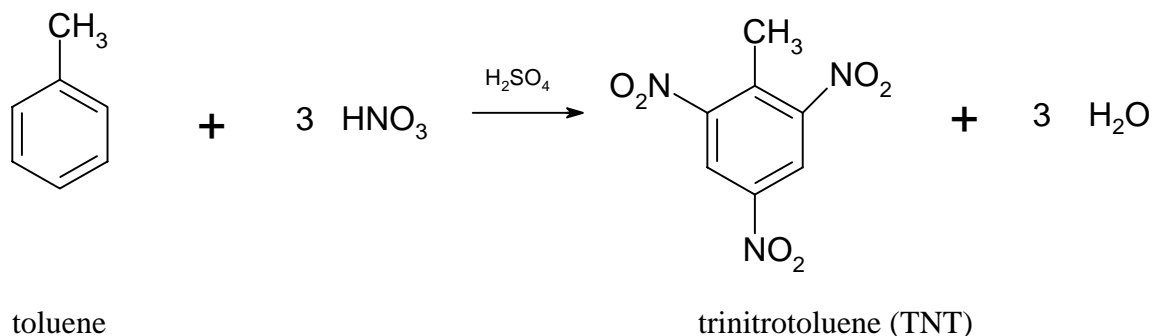


For most organic nitro, nitrate and nitramine compounds, the power and brisance is directly related, to the oxygen balance, and is a maximum when the oxygen balance is close to zero.

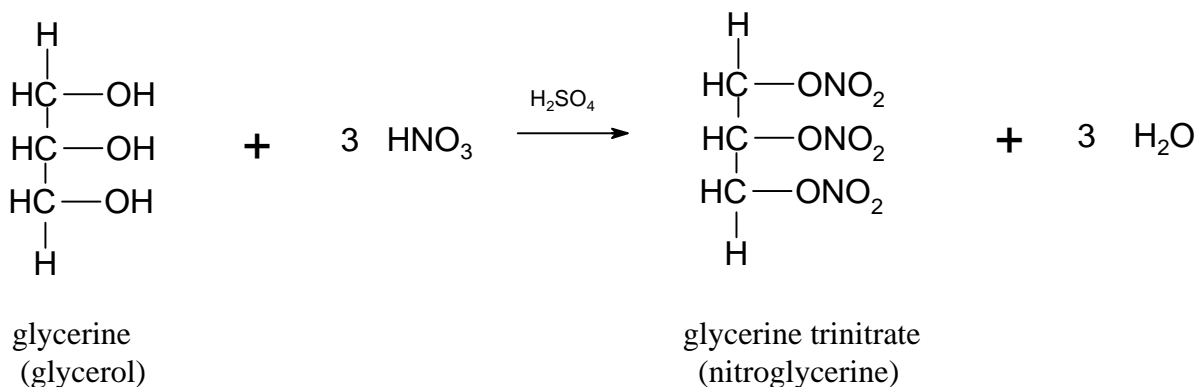
THE NITRATION PROCESS

As mentioned earlier, most explosives are organic compounds, containing nitro (-NO₂), nitrate (-ONO₂) or nitramine (N-NO₂) groups. They are generally prepared by treating a parent compound with a mixture of concentrated nitric and sulfuric acids.

Nitration of an aromatic compound, toluene, for example, proceeds as follows:



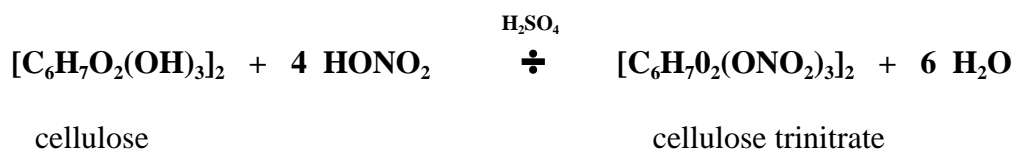
Nitration of a polyhydric alcohol, a compound with several hydroxyl groups, results in the replacement of the hydrogens in the hydroxyl groups with nitro groups and consequent formation of nitrate group. For example, the nitration of glycerine yields glyceryl trinitrate or "nitroglycerine."



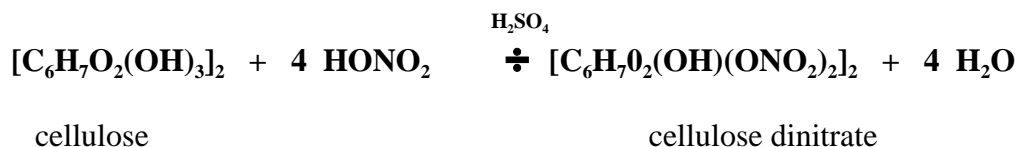
The sulfuric acid remains unchanged, but diluted with water at the end of the reaction. It may, therefore, be considered catalytic in this reaction; the actual mechanism of its action is too complex to discuss here.

Cellulose, a complex molecule that may be considered to be composed of the $[\text{C}_6\text{H}_7\text{O}_2(\text{OH})_3]_2$ unit repeated over and over again, is nitrated just as shown in the example for glycerine. The number of hydroxyl groups in the unit that react with nitric acid is a function of the concentration of the mixed acids, the temperature and the time of the reaction. If a dinitrate is formed, the compound analyzes 11.11% nitrogen, and if a trinitrate is formed the compound analyzes 14.15% nitrogen..

Power grade "nitrocellulose" (cellulose nitrate) contains from 12.5% to 13.5% nitrogen and may be considered a mixture of cellulose dinitrate and cellulose trinitrate.



and



Nitrate and nitro compounds are similar in explosive properties, but the nitrates are less stable chemically and often require the addition of *stabilizers*. Thus nitroglycerine dynamites frequently contain calcium carbonate as a stabilizer, and single base smokeless powders contain the organic stabilizer, diphenylamine.

Both nitrate and nitro compounds, but especially the nitrates, are less stable in the presence of acids. Very careful washing is necessary after nitration. This is especially true with nitrated cotton. The cotton fiber is tubular and the tube remains after nitration. The removal of the last traces of acid from the cellulose nitrate requires chopping the fibers, boiling and washing for many hours.

LOW EXPLOSIVES

Black powder belongs to a class of explosives called *deflagrating* or *low explosives*. Low explosives are substances that burn or explode relatively slowly, the reaction proceeding through the mass only as fast as the flame front. Low explosives react so slowly that they will not produce an explosion unless confined. It is the sudden liberation of gases due to the bursting of the container which produces the effects of the explosion. Enclosure increases the rate of reaction due to the increase in temperature caused by the heat of reaction being confined by the container.

Low or deflagrating explosives are used chiefly as *propellants*, for driving projectiles from guns, for firing rockets, and for powering spacecraft. They are also used for blasting in cases where a slow *heaving effect* is necessary, as in the quarrying of soft rock where large pieces are desired.

Primers

Low explosives used as propellants are not exploded by shock. To explode a low explosive, a flame is required. In guns, the flame is applied by means of a primer. This is a device containing a mixture of chemicals that produces a flame on percussion or is ignited by a electrically heated wire. The primer ignites the charge directly or through the agency of a *igniter* such as black powder. The primer functions in a similar fashion to the chemical mixture on a matchhead. It furnishes the energy to start the combustion by producing flame. By contrast, the principal function of a *detonator* is to produce a shock wave.

Sensitivity

Sensitivity of an explosive is a measure of its tendency to explode after receiving a blow (*percussion*). It is frequently determined by means of a *drop-test*. In general, the absolute values of different workers do not agree well with one another. However, the order of sensitivity will

normally be the same for a list of explosives measured on the various machines. In one such test, the sensitivity is expressed in terms of the distance through which a standard weight must drop onto the material to cause explosion of the material.

One should not infer that sensitivity of an explosive is correlated with thermodynamic instability of that explosive. Lead azide, for instance, is quite sensitive but it is one of the more thermodynamically stable of the explosives.

The sensitivity and detonation rates of some high explosives are listed below:

| Explosive | Sensitivity (2 kg.wt. drop test) | Velocity of Detonation (m/s) |
|-----------------------------------|---|---|
| Mercury Fulminate (loose) | 2 | 1200 |
| Mercury Fulminate (compressed) | | 5000 |
| Nitroglycerine | 4 | 7800 |
| Iron Picrate | 7 | 5000 |
| Dynamite (75% nitroglycerine) | 7 | 5000 |
| Guncotton (loose and dry) | 7 | 3800 |
| PETN | 20 | 8000 |
| RDX(cyclonite) | 30 | 8500 |
| Tetryl | 50 | 7300 |
| TNT (granular) | 90 | 4800 |
| TNT (cast) | 150 | 5700 |
| Ammonia Picrate | > 150 | 5700 |

Explosion Train

A typical *explosion train* in a large gun firing an explosive projectile involves (beside the projectile) three units, housed in a brass case: the *primer*, the *igniter* and the *propellant*.

Briefly, the primer consists of a metal case with two alternate means for firing: percussion acting on a sensitive charge and electrical heating of a fine wire. The latter is the preferred method; the first being used for emergencies. The electric current heats a platinum wire to incandescence and ignites a wisp of dry guncotton wrapped around it. The resultant flame explodes the sensitive initiating explosive, such as mercury fulminate, which sets fire to the primer composition, which in turn ignites a small charge of black powder called the igniter. The resulting flame shoots out and ignites the grains of smokeless powder. Black powder is used because it is easily ignited to

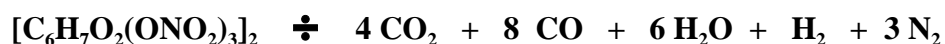
produce the very hot flame necessary to ignite all the grains of smokeless powder at practically the same instant.

A typical primer will consist of a case containing an initiating explosive such as mercury fulminate, an oxidizing agent such as potassium chlorate or barium nitrate, and a fuel such as antimony sulfide.

The propellant is a smokeless powder whose composition and grain shape is adjusted to give the desired properties. The grains are shaped to give the propellant specific burning characteristics. The shape of grains used for rocket motors are varied, and usually quite different from the shape of grains used in guns. Smokeless powder grains used in guns are cylindrical in shape and are perforated with from one to seven tubes, symmetrically arranged and parallel to the length of the cylinder. The rate of burning of the propellant is a function of its surface area. When a solid cylinder burns, its surface area decreases with time and, all other factors being constant, the rate of burning will *decrease* - this is spoken of as *degressive* burning. When multiperforated grains burn, the surface area *increases* with time; this causes an increase in the rate of burning, all other factors being constant, which is spoken of as *progressive* burning.

Smokeless Powder

Considering smokeless powder as containing colloidal $[C_6H_7O_2(ONO_2)_3]_2$, we may write an equation to indicate the approximate reaction on deflagration:



Some of the products are flammable (H_2 and CO). They contribute to the flash of gunfire, and if precautions are not observed, linger in the barrel of the gun to ignite the next charge (*flareback*).

If the explosive contained more oxygen, there would be less flammable products, and the heat of reaction would be higher because of the complete oxidation of carbon and hydrogen. The result would be a higher temperature and a more powerful explosive.

The oxygen may best be introduced by mixing in an explosive containing an excess of oxygen over that required for its complete combustion (positive oxygen balance). Nitroglycerine is such an explosive and explodes approximately according to the following equation:



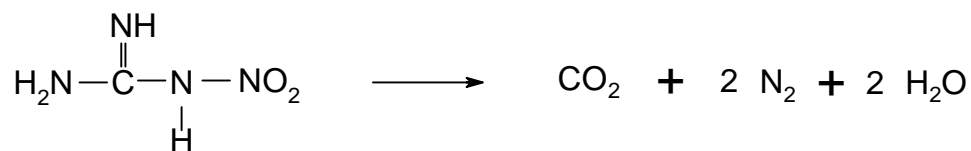
In 1888, Alfred Nobel developed a smokeless powder that he called *Ballistite*; it was a gelatinized mixture of nitroglycerine and guncotton. This type of powder is called a *double base powder* as contrasted with one containing only gelatinized cellulose nitrate, which is a single base powder. The following year, Abel and Dewar incorporated a small amount of mineral jelly into the mixture to stabilize the product and reduce the temperature of explosion. They called the resulting material, extruded through dies into a rope-like shape, *Cordite*. There are several other minor differences, but today the names Cordite and Ballistite are often used interchangeably for any double base powder; that is, for any powder containing both nitrocellulose and nitroglycerine.

The advantages of Ballistite and Cordite are (1) greater energy and (2) more uniform ballistic properties. The disadvantages are (1) somewhat greater danger in manufacture and (2) somewhat greater erosion of the gun.

Erosion is the wearing away of the metal of the gun liner by the passage of the hot gases. Because this is more serious at higher temperatures, the higher energy of Ballistite is obtained at the expense of greater gun wear. For this reason, our armed forces decided against the use of Cordite or Ballistite in large caliber guns until late in World War II when modified Ballistites, which contained agents that reduced the gas temperature, were introduced. Double base powders of various composition are now in general use as propellants for guns, rockets, bazookas and space craft.

The discharge of a gun firing ordinary charges of smokeless powder produces bright flashes from the muzzle which, at night, would disclose the position to the enemy. The flash from a large gun is visible at night for a distance much farther than the sound of the gun can be heard. The flash is caused by the hot combustible gases from the explosion igniting when they come in contact with the oxygen of the air.

Nitroguanidine or other "cold" explosive is often incorporated into the smokeless powder to reduce the flash; it explodes approximately as indicated by the equation:



HIGH EXPLOSIVES

The rate of reaction of *high* or *detonating* explosives is very fast. Whereas the reaction proceeds through a low explosive at rates of a few meters per second, the reaction proceeds through high explosives at several thousands of meters per second. This high velocity is due to the peculiar explosion mechanism of the process. When the first portion explodes, it produces a *shock wave* that travels through the mass with a velocity much greater than the rate of heat transfer. This shock wave activates the molecules and causes their decomposition and rearrangement with a great release of energy. In high explosives, the shock wave travels well in advance of the burning front. In low explosives, the explosive front is maintained by energy being transferred from molecule to nearby molecule, a rapid burning process.

A material that explodes by the mechanism described for high explosives is said to *detonate*. The more rapidly it detonates, the greater the shattering effect. This shattering effect is called *brisance*.

There is a distinct difference between the effect produced by the detonation of a high explosive and by the explosion of a propellant. In a high explosive, the detonation is so rapid that the air does not have time to move out of the way. As a result, a compression wave, or *blast effect*, characteristic of an explosion, is produced. A stick of dynamite merely placed unconfined on the top of a board and detonated will shatter the board. However, the effect of the explosion would have been increased by confinement. The compression wave produced by a high explosive is stronger than that produced by a confined low explosive. The destructive effects are due to much more rapidly applied force, called a *shock wave*, so the effect of a high explosive is to shatter rather than to heave.

High explosives are used for or arming projectiles, mines, depth charges, torpedoes etc., where a maximum destructive effect is desired. They are also used in blasting hard rock - rock which is wanted in small pieces -, and in situations where it would be impossible to tamp a low explosive sufficiently to confine the gases.

It is interesting that many high explosives will burn or deflagrate quietly when ignited by a flame. However, if a large mass of explosive catches fire, it usually burns quietly until the temperature of the interior rises high enough to cause detonation. This fact was vividly illustrated in 1947 when a shipload of ammonium nitrate (NH_4NO_3) intended for use as fertilizer detonated with great loss of life and property after burning quietly for several days in the harbor at Texas City, Texas.

Photos and stories about the 1947 Texas City explosion:
<http://www.chron.com/content/chronicle/metropolitan/txcity/index.html>

Detonators

The detonation of a high explosive is usually initiated by shock. The shock is usually applied by means of a small charge of explosive, called a *detonator*, placed in contact with the main charge. Detonators, frequently called primary *high explosives*, are characterized by great *sensitivity* to shock or heat and by high brisance. The

detonators may be designed to explode either by percussion or by flame. *Mercury fulminate* can be exploded by either method; however, it owes its success as initiating agent primarily to the fact that it explodes easily from fire. *Lead azide* is a more efficient detonating agent than mercury fulminate, that is, it requires a smaller weight of lead azide than mercury fulminate to initiate the detonation of a high explosive. Lead azide does not lose its initiating power on long storage as does mercury fulminate, and the temperature at which it undergoes spontaneous explosion is considerably higher than the spontaneous decomposition temperature of fulminate. However, lead azide pressed into place in a detonator capsule explodes less readily from spark or flame than does mercury fulminate. This defect may be somewhat overcome by coating the lead azide with a layer of lead styphnate or with a lead styphnate-lead azide mixture. Lead azide is not used where it is desired to produce flame from impact. Instead, lead azide is used only as a source of an initiating shock wave for the detonation of a high explosive.

Boosters

The detonation rate of some common high explosives depends, within limits, on the force of the initiating shock. Such explosives are called *secondary detonating explosives*. To obtain the maximum brisance in the explosion of a less sensitive secondary high explosive, such as TNT, it is necessary for the initial shock to be very powerful. Rather than increase the quantity of detonator, which increases the dangers in manufacture and handling, the detonator is supplemented by a charge of secondary explosive of intermediate sensitivity called a *booster*. The booster is an explosive that picks up the impulse of the detonator, amplifies it and explodes the main charge of high explosive. Boosters are found in all major caliber shells and in most bombs, but not in small caliber explosive shells. *Tetryl*, *PETN* and *granular TNT* are explosives frequently used as boosters.

Brisance

Brisance is a loosely used term - it refers to the destruction effect or shattering power of an explosive. It is related to magnitude, and to the speed of establishment, of both the compression wave in air and the detonation wave through the explosive.

At least three major factors are known to influence the detonation rate. They are (1) method of initiation of the explosion; (2) size and confinement of the charge; and (3) physical conditions such as density and temperature. Hence, the same explosive may be more or less brisant, depending on the above factors.

Brisance is measured by several tests, such as a sand crushing test (which measures as the weight of sand in grams crushed by a fixed weight of explosive fired in a standard sand bomb), by a plate denting test, and by the Trauzl test in which high explosives are fired in holes drilled into lead blocks. In the latter case, the resulting increase in the cavity volume is measured. Again, the brisance or shattering effect is related to the rate of detonation.

Warheads

The purpose of a *warhead* is to deliver shattering force to the target. For that reason, high explosives are used, along with a system that delays the explosion until the target is either struck

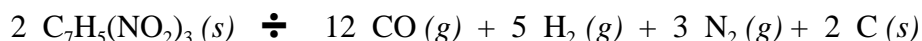
or is in close proximity (depending on the damage desired). The description below for impact-triggering emphasizes the explosive train. The train stays much the same for more sophisticated fuses, but the ignition may be by electric heating rather than by percussion.

When the explosive projectile reaches the target, a small hammer moves forward with the shock of impact and strikes a detonator which explodes and ignites a time fuse of compressed black powder. The time fuse after a predetermined delay detonates a charge of mercury fulminate, or a lead styphnate-lead azide mixture, which in turn detonates a booster such as tetryl, and the latter detonates the main disruptive charge in the projectile.

Disruptives

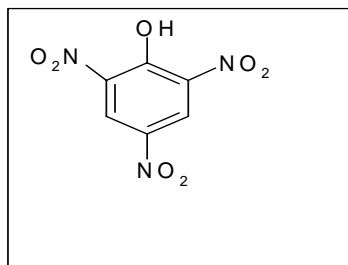
Trinitrotoluene (TNT) is made by the nitration of toluene. It is a common ingredient in shell fillings, either by itself or mixed with other explosives. It possesses the advantage that it may be safely melted by steam, and cast into the shells.

In the cast form, it is relatively insensitive and requires a booster for most effective detonation. TNT explodes approximately as indicated by the equation:



Finely divided solid carbon is formed as one of the products, and this results in a characteristic black smoke.

Picric Acid is trinitrophenol. It is an excellent explosive. Unfortunately, it is also a strong acid that reacts with iron to form the extremely sensitive and dangerous iron picrate. Hence, it cannot be cast directly into steel shells.

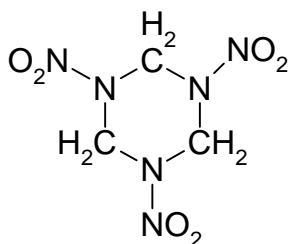


picric acid (trinitrophenol)

Explosive D. For many years the only filling suitable for armor-piercing shells was black powder. All of the known high explosives were so sensitive that they would explode with the impact of the projectile, instead of permitting the necessary time delay.

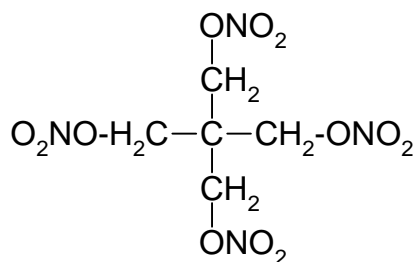
During World War I, it was found that the ammonium salt of picric acid displayed extremely high resistance to impact, shock and friction. It was capable of withstanding the impact shock of a shell passing through armor plate, which TNT cannot do. It was known as the secret "*Explosive D*" (for Colonel Dunn, its developer) that was used in armor-piercing (AP) projectiles during WW I. It is still of considerable importance in AP projectiles, either alone or mixed with 30% TNT.

RDX or Cyclonite is prepared by nitration from hexamethylenetetramine. Although exploded by a 9 inch drop of a two kg. weight in the standard drop weight apparatus, means have been developed to greatly reduce its sensitivity, so that it may be used safely in bombs, shells, torpedoes and mines. Its development and use is considered one of the important R&D achievements in the explosive art.



RDX

PETN is pentaerythritol tetranitrate. It is the most stable thermodynamically, and least reactive chemically, of the explosive nitric esters. It is extremely sensitive to detonation by shock. This, combined with its great brisance, makes it exceptionally useful in compound detonators.



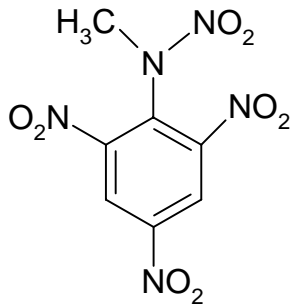
PETN

Plastic explosives are high explosives made into a plastic mass by incorporating various non-explosives and semi-explosive oils, waxes and nitro compounds. Molded into long flexible cords, they can be carried like a coil of line, wrapped around the waist or suspended from the shoulders. Lengths of the required size can be torn off and, for example, pressed between the flanges of a steel girder. Detonation of a plastic explosive wrapped around several key bridge girders will result in the destruction of the bridge.

"Composition C-3", the standard plastic explosive of WW II, is composed of 71% RDX, 3% Tetryl, 6% plasticizing oil, 4% TNT, 10% DNT, plus other ingredients.

OTHER IMPORTANT EXPLOSIVES

Tetryl is the most important explosive used as a booster. It is also a satisfactory disruptive. Only its cost prevents its greater use for this purpose. Certain small shells do have a filling of pure tetryl. The basic chemistry of tetryl is complicated. Chemically, it is N-methyl-2,4,6-trinitrophenylnitrarnine.



Tetryl

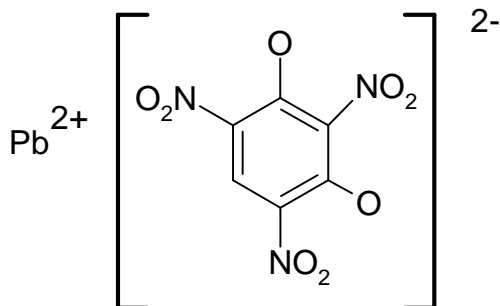
Mercury fulminate, prepared by Howard in 1800, is the material used in most primers. It is also used in many detonators.



Lead azide is the standard detonator used in most explosive shells. It is not detonated by flame unless treated with lead styphnate.



Lead styphnate, used with lead azide in detonators; causes lead azide to initiate from flame.



Lead Styphnate

Amatol is a mixture of ammonium nitrate with TNT. It was used to a limited extent by all combatants in WW II as a substitute for pure TNT.

Baratol is a mixture of 88 to 90% TNT with 10 to 12% barium nitrate. It melts from 80 to 95 °C, depending on composition, and hence may be cast. Its great stability on storage makes it suitable for use in certain ordnance items.

ANFO, which stands for Ammonium Nitrate-Fuel Oil, has nearly replaced dynamite as a rock blasting material in civilian use. The necessary oxygen balance can be obtained by mixing the

two components, and the shelf life is not a consideration since the ANFO can be prepared as needed. It detonates with much the same performance as dynamite and can be initiated by blasting caps in the same way. The slurry is poured into bore holes in the rock and then armed. This material was used for the infamous 1995 bombing of the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma - the worst incident of domestic terrorism ever recorded in the US. The ready availability of the components, and the simplicity of the mixture, make ANFO a potent weapon of terrorists.