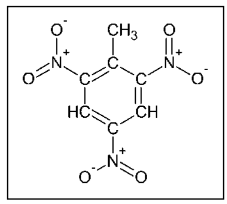
91. Thymine. See 29. Cytosine, Thymine, and Uracil

92. Trinitrotoluene (TNT)

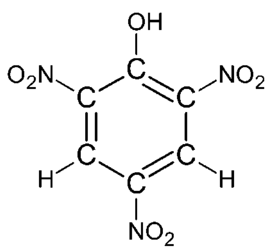


CHEMICAL NAME = methyl-2,4,6-trinitrobenzene
CAS NUMBER = 118–96–7
MOLECULAR FORMULA = $C_7H_5N_3O_6$
MOLAR MASS = 227.1 g/mol
COMPOSITION = C(37.0%) H(2.2%) N(18.5%) O(42.3%)
MELTING POINT = 80.1°C
BOILING POINT = unstable, explodes at 240°C
DENSITY = 1.65 g/cm^3

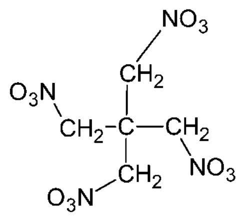
TNT is the abbreviation of the aromatic nitrated aromatic compound 2,4,6-trinitrotoluene. It is a pale-yellow crystalline solid that was first synthesized in 1863 by the German chemist Joseph Wilbrand (1811–1894), but it was not immediately used as an explosive. TNT is made by nitrating toluene using nitric acid, sulfuric acid, and oleum (a mixture of sulfuric acid and SO_3). Nitration of toluene occurs in stages, with the nitro units added sequentially in a stepwise process as the reaction proceeds. The last nitro unit is accomplished by using oleum (SO_3 dissolved in sulfuric acid). After nitration, unused acids are recycled, and the product is washed with sodium sulfite and water to remove impurities.

TNT is one of the most common explosives. Unlike nitroglycerin, TNT will not explode when subjected to significant shock and friction. It is classified as a secondary explosive, which means it requires an initiating explosive to detonate. The Germans began production of TNT in the last decade of the 19th century, and it was used in the mining industry. Military engineers adapted mining explosives for use in warfare, and TNT started to be incorporated in munitions in 1902. The first widespread use of TNT occurred during World War I. It had several advantages over picric acid, which had been used widely in munitions during the latter half of the 19th century and the first part of the 20th century. Unlike TNT, picric acid was much more likely to detonate when disturbed. Furthermore, picric acid could react with the metal in artillery shells, producing explosive picrate compounds. TNT did not react with metal and its low melting point meant it could be melted using steam and poured into shells. TNT's ability to withstand shock was an advantage in penetrating the armor of ships, tanks, and other metal-plated objects. TNT shells equipped with an appropriate fuse could penetrate objects and cause maximum damage on detonation. In contrast, picric acid shells would explode after striking an object. The British made extensive use of picric acid shells in World War I, which was called lyddite after the town of Lydd in England where it was manufactured; the Germans made greater use of TNT. Although picric acid had more explosive power, the Allies began to use more TNT because of its ability to penetrate armor without detonating prematurely.

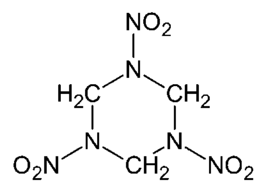
Between World War I and II, TNT replaced picric acid as the explosive of choice in munitions. It was also mixed with other compounds to produce more powerful explosives with unique characteristics. Amatol is a mixture containing between 40% and 80% ammonium nitrate and TNT. Pentolite is a mixture of PETN (pentaerythritol tetranitrate) and TNT. Another common explosive mixture is RDX (cyclotrimethylenetrinitramine) and TNT. RDX is an abbreviation for Royal Demolition Explosive.



picric acid



PETN



RDX

TNT's explosive power results from the quick formation of stable gaseous products when TNT is detonated. The explosive reaction of TNT can be represented as: $2C_7H_5N_3O_{6(s)} \rightarrow 3N_{2(g)} + 7CO_{(g)} + 5H_2O_{(g)} + 7C_{(s)}$. On reaction, the volume of the products is a thousand times that of the TNT reactant. The rapid increase of volume causes the explosion. TNT's explosive power is used as a standard for energy, which is especially useful in rating explosives. Because the precise amount of energy release is difficult to calculate, 1 kiloton of TNT is defined as releasing 10^{12} calories of energy. Based on this equivalency, a thousand tons, 1 kiloton, would release 4.2×10^{12} joules; and a million tons, a megaton, releases 4.2×10^{15} joules. Nuclear weapons are rated in terms of megaton. The atomic bombs used in World War II were approximately 20 kilotons. Modern nuclear warheads have ratings on the order of several megatons.

TNT has limited use as a chemical intermediate in pharmaceuticals and for photographic chemicals. It is used to produce other nitrated compounds. Removing the methyl group from TNT produces 1,3,5-trinitobenzene, and removing methyl and a nitro group produces 1,3-dinitrobenzenze (1,3-DNB). Both trinitrobenzene and dinitrobenzene can be used as explosives. Trinitrobenzene is more powerful than TNT but less sensitive to impact. Dinitrobenzene has been used in the production of nitrocellulose, which is used for smokeless gunpowder and guncotton.