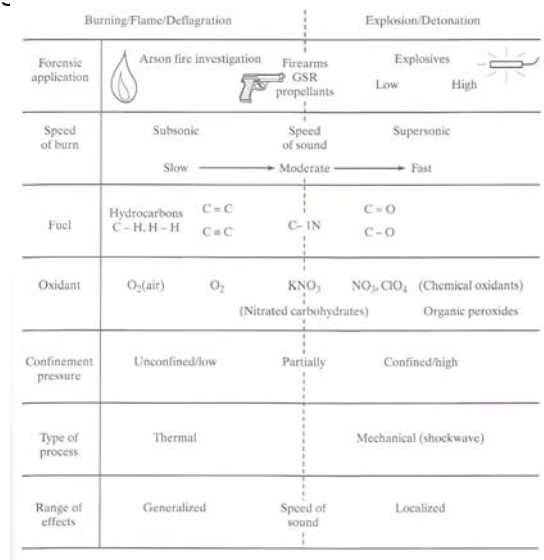
Explosives



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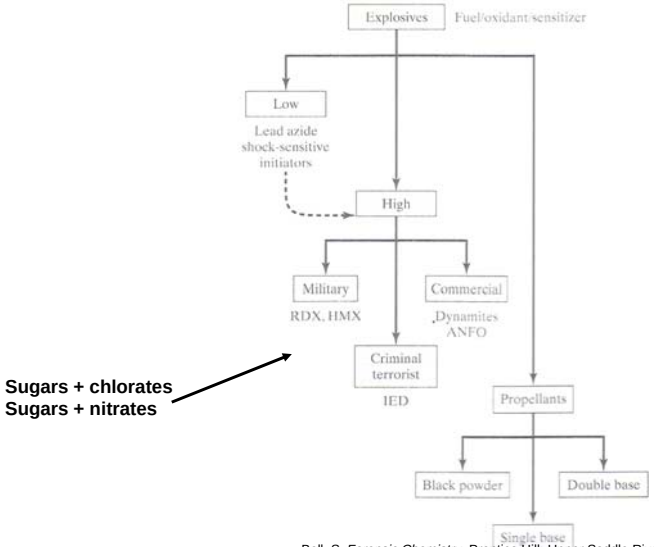
1

Explosives: categorization



Sugars + chlorates
Sugars + nitrates

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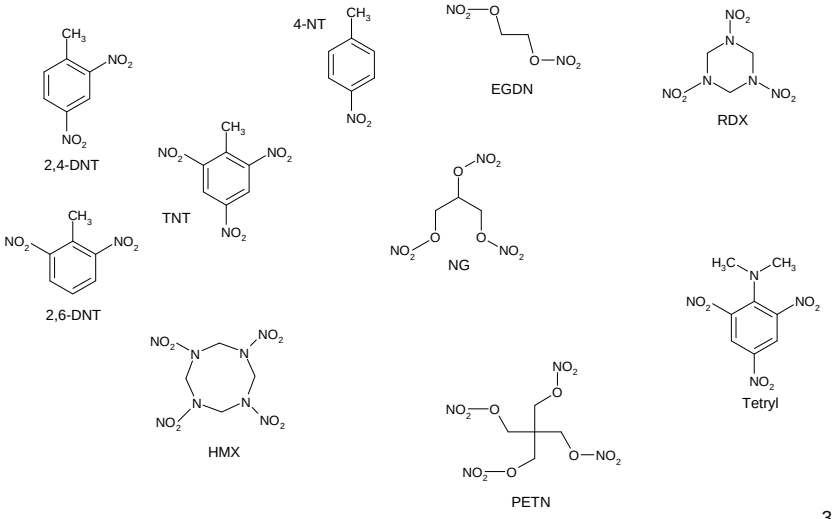
2

Structures of common explosives



3

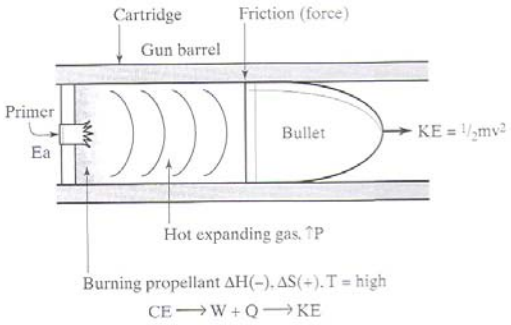
Explosives

- Mixture of reduced and highly- oxidized elements
- Thermal activation causes rearrangements
  - small molecules produced
  - large ΔS & large ΔG
  - Can do lots of work!
- Propagation of pressure "shockwave"
  - 1500-10,000 m/s
  - Speed sound ~350 m/s in air
    - (3,500 m/s in water, >10,000 in glass)
- High explosives
  - Primary = shock and spark sensitive (NG)
  - Secondary = not sensitive, require detonating (TNT)

4

Gunpowder & propellants

- Gas expansion used to propel projectiles
- Need steady gas expansion to accelerate bullet
- Primer (PbN_3), Lead styphr
  - Low E_a
- Deflagrant (not explosive)
  - Single base
    - Nitrocellulose
  - Double base
    - Nitrocellulose + NG
  - Triple base
    - Nitrocellulose + NG + n
    - For V. large propellants



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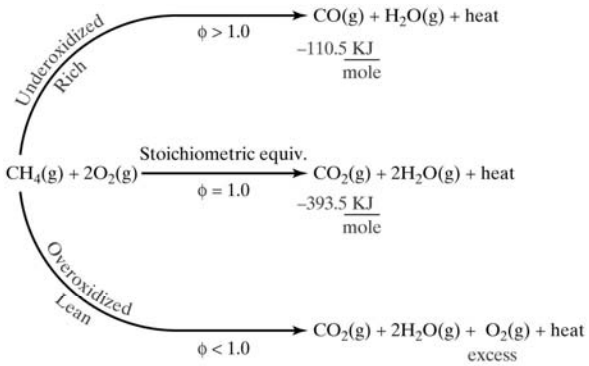
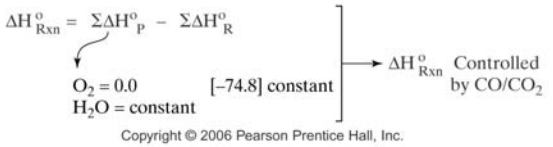




6

Oxygen Balance: A concept for evaluating high explosives.

1. $C_7H_5N_3O_6 \rightarrow N_2 + CO_2 + H_2O$
   write reactant and products without O_2
2. $C_7H_5N_3O_6 \rightarrow 1.5N_2 + 7CO_2 + 2.5H_2O$
   balance without O_2 and keeping explosive at unity
3. 10.5 O $C_7H_5N_3O_6 \rightarrow 1.5N_2 + 7CO_2 + 2.5H_2O$
   add O to equation for full balance check

$$\%OB = \frac{(O_{available} - O_{needed\ for\ combustion}) * 16}{Mass_{explosive}} * 100$$

$$\%OB = \frac{(6 - 16.5) * 16}{227} * 100$$

$$\%OB = -74\%$$

Oxygen Balance: A concept for evaluating high explosives.

1. $NH_4NO_3 \rightarrow N_2 + CO_2 + H_2O$
   write reactant and products without O_2
2. $NH_4NO_3 \rightarrow N_2 + ØCO_2 + 2H_2O$
   balance without O_2 and keeping explosive at unity
3. $NH_4NO_3 \rightarrow N_2 + ØCO_2 + 2H_2O + 1O$
   add O to equation for full balance check

$$\%OB = \frac{(O_{available} - O_{needed\ for\ combustion}) * 16}{Mass_{explosive}} * 100$$

$$\%OB = \frac{(3 - 2) * 16}{80} * 100$$

$$\%OB = +20\%$$

Oxygen Balance of Some Representative High Explosives

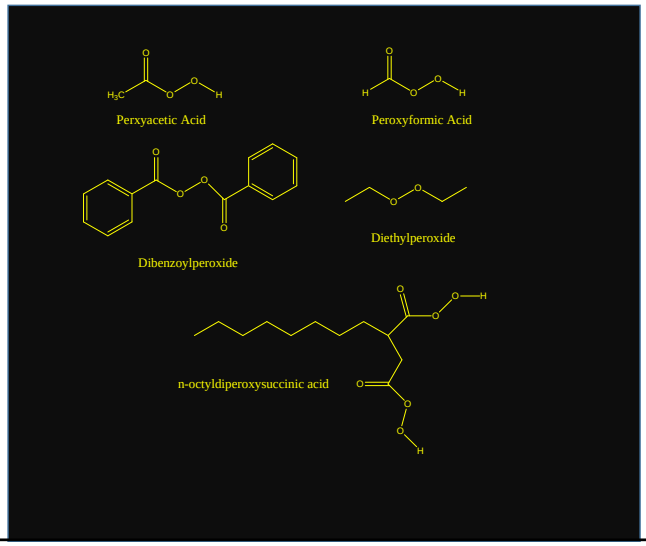
Explosive	%OB
TNT	-74
RDX	-43
Nitroglycerine	+7.0
Ammonium Nitrate	+20

Mixing Explosives to Achieve Optimum %OB

Amatols = mixtures of ammonium nitrate and TNT

ANFO = mixtures of ammonium nitrate and fuel oil

Organic Peroxides – A very different and less predictable class of potentially explosive compounds.



"On 7 July, four bomb blasts on London's transport system killed at least 54 people and injured hundreds more. Evidence led investigators to search houses in Leeds, where three of the four suspected suicide bombers lived. In one house they found traces of triacetone triperoxide (TATP). The white crystalline powder is so unstable that police immediately widened the cordoned-off area and employed a no-fly zone around the site." – newscientist, 2005

Pressure cooker bombs

Sterling Hall Bombing Here at UW:

"…. In the early morning hours of August 24, 1970, the New Years Gang loaded about 2,000 pounds of ammonium nitrate soaked in aviation fuel into a stolen Ford. The group parked the van below the Army Mathematics Research Center, in a driveway of Sterling Hall. At 3:42 A.M. the bomb exploded. It was powerful enough to knock out windows six blocks away, and police found pieces of the Ford van on top of an eight-story building nearby…."

- www.slt.wisc.edu/~pacehandbook

2 ships
6000 metric tons AN
Sulfur
Munitions

"The Texas City Disaster is generally considered the worst industrial accident in American history"

500 dead, 5000 injured, 500 homes destroyed

"On April 19, 1995, a truck-bomb explosion outside the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, left 168 people dead and hundreds more injured. "

The explosion at West Fertilizer resulted from an intense fire in a wooden warehouse building that led to the detonation of approximately 30 tons of AN stored inside in wooden bins. Not only were the warehouse and bins combustible, but the building also contained significant amounts of combustible seeds, which likely contributed to the intensity of the fire. According to available seismic data, the explosion was a very powerful event.

2) Whether additional factors such as material characteristics, shock, or contamination contributed to the incident remains to be determined. Company employees described a PVC plastic pipe that was located directly above the AN bin that detonated, and likely would have been melted by the fire. Additionally, large amounts of potentially flammable anhydrous ammonia were stored along the southern edge of the warehouse building.

3) The building lacked a sprinkler system or other systems to automatically detect or suppress fire, especially when the building was unoccupied after hours. By the time firefighters were able to reach the site, the fire was intense and out of control. Just 20 minutes after the first notification to the West Volunteer Fire Department, the detonation occurred.