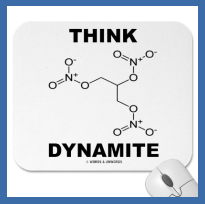
LECTURE 11

EXPLOSIVES AND PROPELLANTS



Ch 61 Industrial Chem

EXPLOSIVES

- is a material that undergoes a rapid and spontaneous decomposition releasing large volumes of gases and heat when subjected to a thermal or mechanical shock.

THREE FUNDAMENTAL TYPES:
MECHANICAL, ATOMIC, and CHEMICAL

EXPLOSIVES

- rapid chemical rupturing of bonds progressing directly through the mass of the explosive.
- it is the rate of energy release rather than the total energy that makes a product explosive.
- Nitroglycerine has only 1/8 the energy of an equivalent wt of gasoline.

Sterling Hall Bombing at the University of Washington

"…. 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…."

EXPLOSIVES - USES

Used in mining and quarrying, construction, geophysical exploration, metal cutting and forming

Engineering jobs such as construction of tunnels and dams.

Mount Cenis, a 13-kilometer railway tunnel driven through the Alps between France and Italy was a benchmark for the use of explosives.

Three Gorges Dam - China

- Demolition experts used some 200 tons (181 metric tons) of explosives to destroy the final Three Gorges dam—a temporary construction that had allowed builders to finish the dam's massive main wall.

- The blast created some 243,278 cubic yards (186,000 cubic meters) of concrete rubble.
- enough explosives to level 400 ten-story buildings

TYPES OF EXPLOSIVES

DETONATING: (high explosives) – detonates at very high rates, 2 to 9 x 10^3 m/sec

A) Primary or initiating explosives

B) Booster and secondary explosives

DEFLAGRATING: (or low explosives or propellants) – burn at low rates ~ 10^{-2} m/sec – reaction front is a flame)

HIGH EXPLOSIVES BURN AT SUPERSONIC SPEEDS!!

CONFLAGRATION: rapid burning with a flame front traveling through the material at 1 m/sec to 300 m/sec.

DETONATION: "instantaneous" burning with flame front traveling through the material at 1000 m/sec to 3000 m/sec resulting in a supersonic shock wave.

PRIMARY EXPLOSIVES

- shock or heat sensitive materials
- can explode with application of flame, spark, friction, or heat source
- are usually inorganic salts; $Hg(ONC)_2$, $Pb(N_3)_2$ lead trinitro resorcinate, diazodinitrophenol, tetrazine

AN EXPLOSIVE FORMULATION

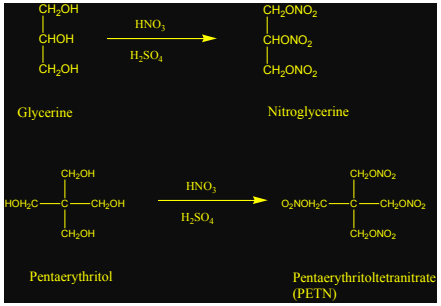
Antimony sulfide:	15%
Lead azide	20%
Basic lead styphanate	40%
Barium nitrate	20%
Tetrazine	5%

Others: glue, ground glass

BOOSTER HIGH EXPLOSIVES

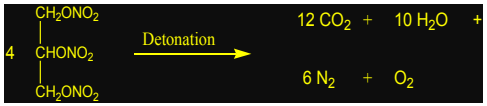
- insensitive to mechanical shock and flame
- set off by another explosive shock

EARLY EXAMPLES OF PRIMARY HIGH EXPLOSIVES



NITROGLYCERIN

- Nitroglycerine detonates by rapidly rearranging to a collection of small stable gas molecules releasing a huge quantity of heat and pressure.



- Pure Nitroglycerine is way too "sensitive" to be a useful explosive. It was the invention of dynamite by Alfred Nobel that converted nitroglycerine into a useful commercial and military explosive by mixing nitroglycerine with clay (diatomaceous earth) and forming the mixture into dynamite sticks.

EXPLOSIVE CHARACTERISTICS

- Heat values, rates of combustions, detonation, shattering ability (brisance), sensitivity are measured values.

Table 22.2 Summary of Characteristics of Explosives

Name	Formula	Products per Formula Weight	Q_v, J/kg	T_e, °C	f, kg/cm²	V, m/s	Trauzl Expansion, cc/10 g	Potential, $\times 10^5$ kg-m
Gunpowder	$2KNO_3 + 3C + S$	$N_2 + 3CO_2 + K_2S$	2098	2090	2,970	—	30	2.1
Nitrocellulose	$C_{24}H_{29}O_9(NO_3)_{11}$	$20.5CO + 3.5CO_2 + 14.5H_2O + 5.5N_2$	5234	2800	10,000	6100	420	5.3
Nitroglycerin	$C_3H_5(NO_3)_3$	$3CO_2 + 2.5H_2O + 1.5N_2 + 0.25O_2$	6389	3360	9,835	8500	590	6.5
Ammonium nitrate	NH_4NO_3	$2H_2O + N_2 + 0.5O_2$	1608	1100	5,100	4100	300	1.6
TNT	$C_7H_5(NO_2)_3$	$6CO + C + 2.5H_2 + 1.5N_2$	2747	2200	8,386	6800	260	2.8
Picric acid	$C_6H_2(OH)(NO_2)_3$	$6CO + H_2O + 0.5H_2 + 1.5N_2$	3546	2717	9,960	7000	300	3.6
Ammonium picrate	$C_6H_2(NO_2)_3ONH_4$	$6CO + H_2O + 2H_2 + 2N_2$	2604	1979	8,537	6500	230	2.6
Tetryl	$C_7H_5N_5O_8$	$7CO + H_2O + 1.5H_2 + 2.5N_2$	3802	2781	10,830	7229	320	3.9
Mercury fulminate	$Hg(ONC)_2$	$Hg + 2CO + N_2$	1759	4105	5,212	3920	213	1.8
Lead azide	PbN_6	$Pb + 3N_2$	2864	3180	8,070	5000	250	2.9

SOURCE: After Meyer, *Science of Explosives*, Crowell, New York, 1943; for more recent investigations of characteristics of explosives, cf., Cook, *Science of High Explosives*, ACS Monograph 139, Reinhold, New York, 1958, p. 284, table 12.1; a more extensive list will be found in Riegel, *Industrial Chemistry*, 7th ed., Reinhold, New York, 1974, pp. 570–596.

NOTE: Q_v = heat of explosion at constant volume (small in comparison with fuels, but explosives exert their energy rapidly); T_e = explosion temperature, f = specific pressure, i.e., exerted by 1 kg in a volume of 1 L at T_e heat; V = velocity of detonation wave (currently measured by high-speed photography).

BLASTING AGENTS AND SLURRY EXPLOSIVES

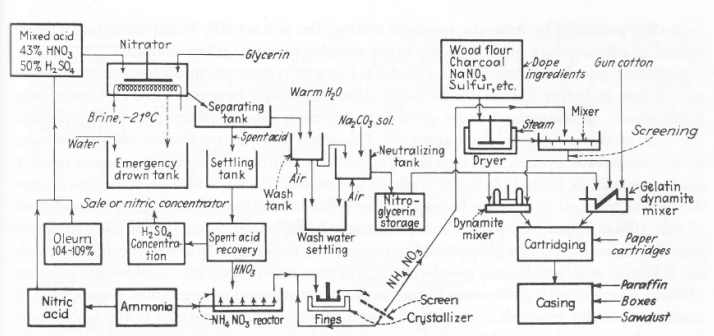
- **BLASTING AGENT** - any material or mixture, consisting of a fuel and oxidizer, intended for blasting, where one of the ingredients are classified as an explosive, provided that the finished product, as mixed and packaged for use or shipment, cannot be detonated by means of blasting cap when unconfined.

BLASTING AGENTS AND SLURRY EXPLOSIVES

- Simpler handling
- Low cost
- Safer – not easily detonated
- Usually ammonium nitrate mixed with nonexplosive fuels such as oil or wax.
- Ammonium nitrate is the worlds most widely used explosive substance.

NITROGLYCERIN AND DYNAMITE

- Produced by nitration of glycerin using about 60/40 mixture of H_2SO_4 and HNO_3

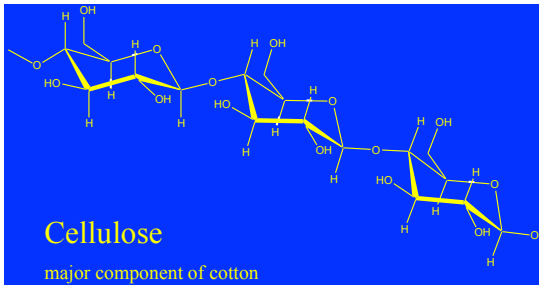


PROPELLANTS, ROCKETS and MISSILES

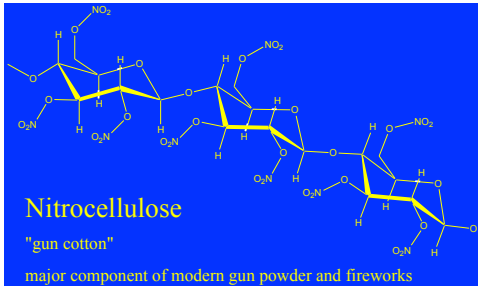
PROPELLANTS FOR GUNS

- oldest propellant is "black powder"
- mixture of charcoal, KNO_3 and sulfur
- replaced by "smokeless" powder
- colloided nitrocellulose + plasticizer = smokeless single-based-powder
- nitrocellulose + nitroglycerin = double-base powder

NITROCELLULOSE

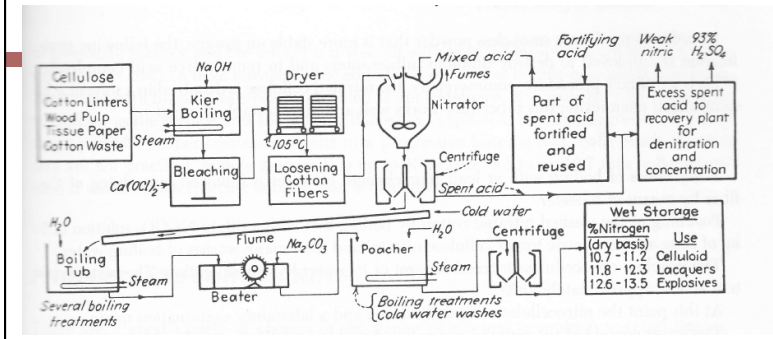


NITROCELLULOSE

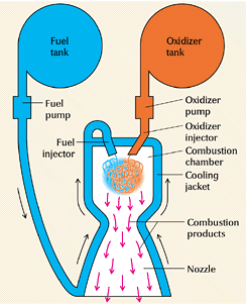


NITROCELLULOSE

- Three hydroxygroups can be nitrated to yeild a theoretical N content of 14 %.
- $C_6H_7O_2(OH)_3 + HONO_3 + (H_2SO_4) \rightarrow C_6H_7O_2(NO_3)_3 + 3H_2O + (H_2SO_4)$



ROCKET PROPELLANTS



- Are low explosives consisting mainly of a fuel and an oxidant
- The thrust of the escaping gases pushes the device forward
- High performance systems are used for missiles and spacecrafts for exploratory.

LIQUID PROPELLANTS

- The fuel, the oxidizer, and the catalyst are all liquids and can be store at different or the same compartments.

SOLID PROPLELLANT SYSTEMS

- Advantage over liquids: simple in design and more easily stored, handled and serviced.

MICELLANEOUS INDUSTRIAL EXPLOSIVES

PYROTECHNICS

MATCHES

MILITARY EXPLOSIVES

TNT

TETRYL

PICRIC ACID

PYROTECHNICS

Sample composition:

Barium nitrate (OA)	34%
Mg (heat)	36%
Aluminum Powder (light)	8%
Calcium Oxalate (yellow tint)	20%
Binders	2%

MATCHES

Strike anywhere matches:

- P_4S_3 - fuel
- $KClO_3$ – oxidizing agent
- binders and glue
- Ground glass

TNT

Multistage nitration of toluene

Normally used in mixtures with ammonium nitrate

Picric Acid 2,4,6-trinitrophenol

Not by direct nitration of phenol but by nitration of phenol sulfonates with mixed H_2SO_4/HNO_3

EXPLOSIVE D – Ammonium picrate