unit 5

1.Explosives &Propellants

M42 Grenades – Over 6 million processed

40 mm Practice Grenade

Explosive

An explosive is

- “a substance or a mixture, which when subjected to thermal or mechanical shock,
- gets very rapidly oxidized exothermically into products of
- greatly increased volume,
- with a sudden release of potential energy.”

Explosive

- ‘A substance or a mixture under the
- influence of thermal or mechanical shock rapidly oxidize and give rise to
- products along with
- a lot of energy are called explosive’

Explosives &Propellants

- ***“power to weight (or volume) ratio.”***

- It is the amount of power available from a

- given weight or volume of explosive.

Explosives &Propellants

- When this extremely rapid chemical change takes place in a *confined space,*
- an extremely high pressure is developed, which *shutters the walls .*
- And if developed in slower controlled rate it may be *used to propel projectiles*.

Explosives &Propellants

Uses of explosives:

both constructive and destructive uses are possible.

1. in industries for blasting ores of iron and other metals.
2. breaking down coals, mining salts & limestones for road making.
3. blasting holes in mountains for making tunnels.

Explosives &Propellants

4. excavating earth for dams, disloading rocks etc.

5. major uses in ammunition not only for wars but supporting purposes also e.g.

6. **aerial bombs, rockets, torpedoes, grenades. etc.**

Explosives &Propellants

Characters of an explosive.

1. its rate of decomposition should be very fast to produce

2. a large volume of gaseous products, exothermically.

3. it should be cheap under normal conditions…….

Explosives &Propellants

4. It must not be volatile and hygroscopic and
5. It should be chemically stable i.e.

6. should not react with the container to form any shock sensitive compound.

Explosives &Propellants

7. It should possess at least 1 weaker bond that can be broken easily,

i.e. should have low energy of dissociation.

Usually contain N-N, N-O, N-Cl and O-Cl bonds.

Explosives &Propellants

8. It should have a positive Oxygen balance.

- Oxygen balance indicates the oxygen contained in the molecule,
- which can be utilized to oxidize the C and H to CO and H_2O

Oxygen balance

- It is the measure of oxygen which will turn to CO & H_2O

$$C_xH_yO_z \longrightarrow xCO + y/2\ H_2O + [z-(x+y/2)]O$$

- Oxygen Balance = $\frac{[z-(x+y/2)] \times 16 \times 100}{\text{Mol. Wt. of } C_xH_yO_z}$

Compound	Mol. wt.	$z-\left(x+\frac{y}{2}\right)$	Oxygen-balance
NH_4NO_3	80	$3-0-\frac{4}{2}=1$	$\frac{1\times16\times100}{80}=20$
$C_6H_3(NO_2)_3$ (TNB)	213	$6-6-\frac{3}{2}=-1.5$	$\frac{-1.5\times16\times100}{213}=-11.3$
$Pb(N_3)_2$ (Lead azide)	290	Zero	Zero
$C_7H_5N_3O_6$ (TNT)	227	$6-\left(7+\frac{5}{2}\right)=-\frac{7}{2}$	$\frac{-3.5\times16\times100}{227}=-24.7$
$C_3H_6N_6O_6$ (RDX)	222	$6-\left(3+\frac{6}{2}\right)=0$	Zero
$C_6H_4N_4O_5$ (DDNP)	196	$5-\left(6+\frac{4}{2}\right)=-3$	$\frac{-3\times16\times100}{196}=-24.5$
$C_5H_8N_4O_{12}$ (PETN)	316	$12-\left(5+\frac{8}{2}\right)=3$	$\frac{3\times16\times100}{316}=15.2$

Cyclomethylene trinitroamine

diazodinitrophenol

Pentaerythryl tetranitrate

Explosives &Propellants

1. Lead azide having no O_2 balance is an explosive.

2. The bonded nitrogen liberates as N_2 gas and no oxygen is required.

3. If No_x is formed then needs calculations.

Explosives &Propellants

3. If No_x is formed then needs calculations.

4. N containing explosives with low O_2 balance form NO but

5. those with high O_2 balance form NO and NO_2 during explosion.

Explosives &Propellants

6. For good results negative O_2 balance materials are mixed with

positive O_2 balance materials.

E.g. TNB and TNT (-ve) are mixed with NH_4 NO_3(+ve).

Explosives &Propellants

7. It should be sensitive to impacts of ***detonators*** or initiating or primary explosives.

8. It should possess ***brisance*** i.e. high shattering power

Explosives &Propellants

Some important terms

1.Sensitivity

- Sensitivity to impacts of
- Detonators (or initiating or primary explosives)

- Since the detonators should explode in a very
- short period of time by the application of
  - heat,
  - friction and/or
  - mechanical impact.

Explosives &Propellants

1.Sensitivity

…….Sensitivity is determined by

- **dropping a standard weight from a height on the detonator.**

- **Lesser the height** for triggering the detonator **better is the sensitivity.**

- Similar things are done for friction and flame.

Explosives &Propellants

- Secondary or high explosives are generally insensitive to

  friction, mechanical shock and fire so

- some sensitizer or boosters are added to it.

  e.g. tetryl (nitroaryl nitroamine)

  and pentolite.

Explosives &Propellants

2. VOD Velocity of detonation :

- is the velocity with which the given explosive detonates.
- It depends upon density or compression of the powdered explosive e.g.for TNT

VOD km/s	**46**	**68.5**	**75**
Density	**1.0**	**1.5**	**1.7**

Explosives &Propellants

3. Explosive strength is

- **the energy** liberated **per unit mass** of explosive (cal/g) or
  compared with blasting gelatine.

- Gelatine is the strongest commercial dynamite
- rated as 100%

4. Brisance

i.e. the shattering power.

CLASSIFICATION

CLASSIFICATION OF EXPLOSIVES

1. Primary or initiating explosives (or detonators)
2. Low explosives (or propellants)
3. High explosives.

S&As, Primers, Detonators

Millions Processed

PRIMARY OR INITIATING EXPLOSIVES OR DETONATORS

- Highly sensitive
- Explode on receiving a slight shock or by fire
- These are used to initiate or start the explosion of the main explosive.
- Which is comparatively less sensitive
- Should be handled with utmost care.

PRIMARY OR INITIATING EXPLOSIVES OR DETONATORS

Lead Azide (PbN_6)

2) Mercury fulminate[$Hg(CNO)_2$]

3)DDNP (diazo dinitro phenol)

4) Tetracene [$C_2H_7N_7O$]

Primary or initiating explosives

or detonators **Lead azide(PbN_6)**

due to its

i) low cost

ii) Excellent initiation

iii) Stability in storage

Very popular for military uses

Primary or initiating explosives or detonators Lead azide (PbN_6)

Disadvantages :

1. Lead Azide cannot initiate

less sensitive secondary explosives like TNT.

2. Lead Azide reacts with brass,

so the caps are made of Aluminium.

Primary or initiating explosives or detonators Lead azide (PbN_6)

MANUFACTURE:

- It is prepared by reacting sodium azide &lead acetate

$$2NaN_3 + (CH_3COO)_2Pb \longrightarrow Pb(N_3)_2 + 2CH_3COONa$$

Lead azide(PbN_6) MANUFACTURE:

- Sodium azide in turn is prepared by sodium amide $NaNH_2$ & nitrous oxide N_2O.

$$6NH_3 + 2\,Na \longrightarrow 2NaNH_2 + 3\,H_2$$

$$NaNH_2 + N_2O \longrightarrow NaN_3 + H_2O$$

Primary or initiating explosives or detonators Lead azide (PbN_6)

MANUFACTURE:

- Then by reacting sodium azide with lead acetate

$$2NaN_3 + (CH_3COO)_2Pb \longrightarrow Pb(N_3)_2 + 2CH_3COONa$$

Sod Azide Lead Acetate Lead Azide Sod. Acetate

$$6\,NH_3 + 2\,Na \longrightarrow 2\,NaNH_2 + 3\,H_2$$

$$NaNH_2 + N_2O \longrightarrow NaN_3 + H_2O$$

$$2\,NaN_3 + Pb(OAc) \longrightarrow Pb(N_3)_2 + 2\,AcONa$$

Sod. azide Lead acetate Lead azide Sod. acetate

Primary or initiating explosives or detonators Lead azide (PbN_6)

- Decomposition reaction:

- $Pb(N_3)_2 \longrightarrow Pb + 3\ N_2 + 0$ Kcal

Primary or initiating explosives or detonators

2) Mercury fulminate[$Hg(CNO)_2$]

- It is more sensitive
- It is also more expensive
- It is little toxic
- Lesser in use

Primary or initiating explosives or detonators 2) Mercury fulminate[$Hg(CNO)_2$]

- Prepared by dissolving Hg in excess of HNO_3
  - This is added to ethanol
  - This mixture is allowed to boil.

- Then the mercury fulminate will be precipitated

Decomposition reaction:

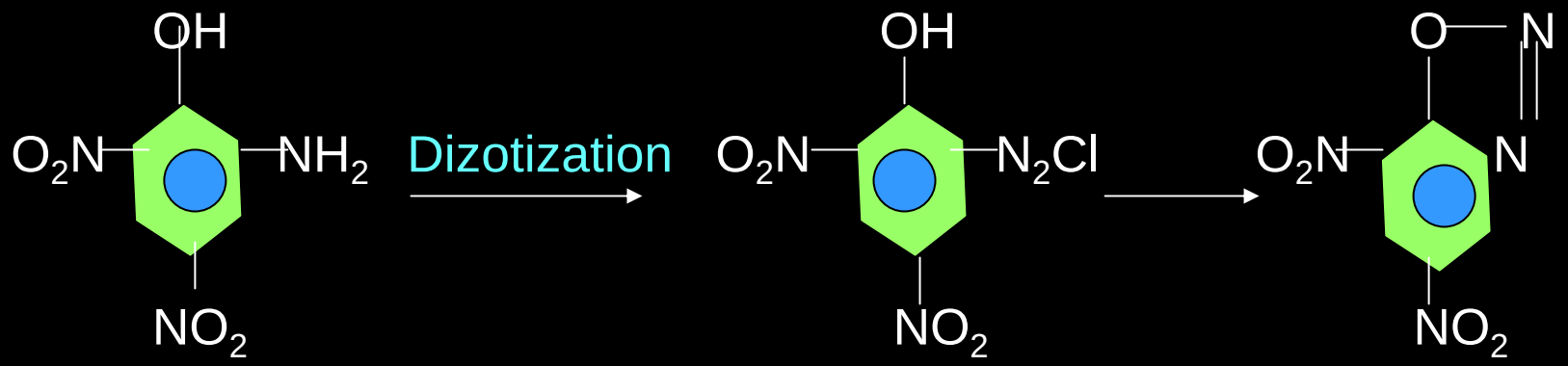
- **$Hg(ONC)_2 \longrightarrow Hg + N_2 + 2CO + 117K\ CAL$**

Primary or initiating explosives or detonators 3)DDNP (diazo dinitro phenol)

- sensitive
- high brisance i.e. high shattering power
- can initiate less sensitive secondary explosives also.
- Widely used in commercial blasting camps.

Primary or initiating explosives or detonators 3)DDNP (diazo dinitro phenol)

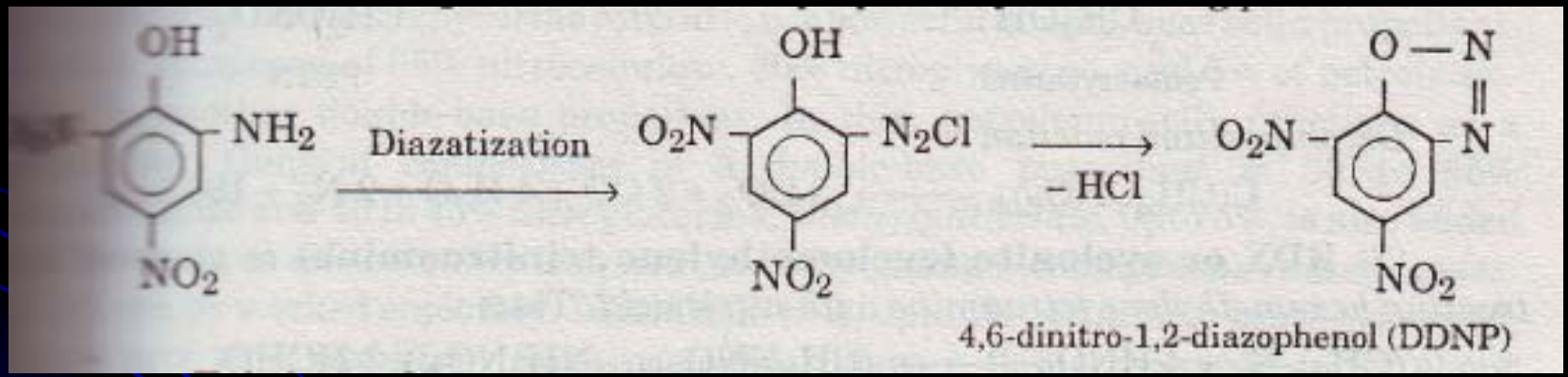
- Diazo dinitro phenol(DDNP) is prepared by diazotization of picramic acid



4,6- dinitro1,2- diazo phenol

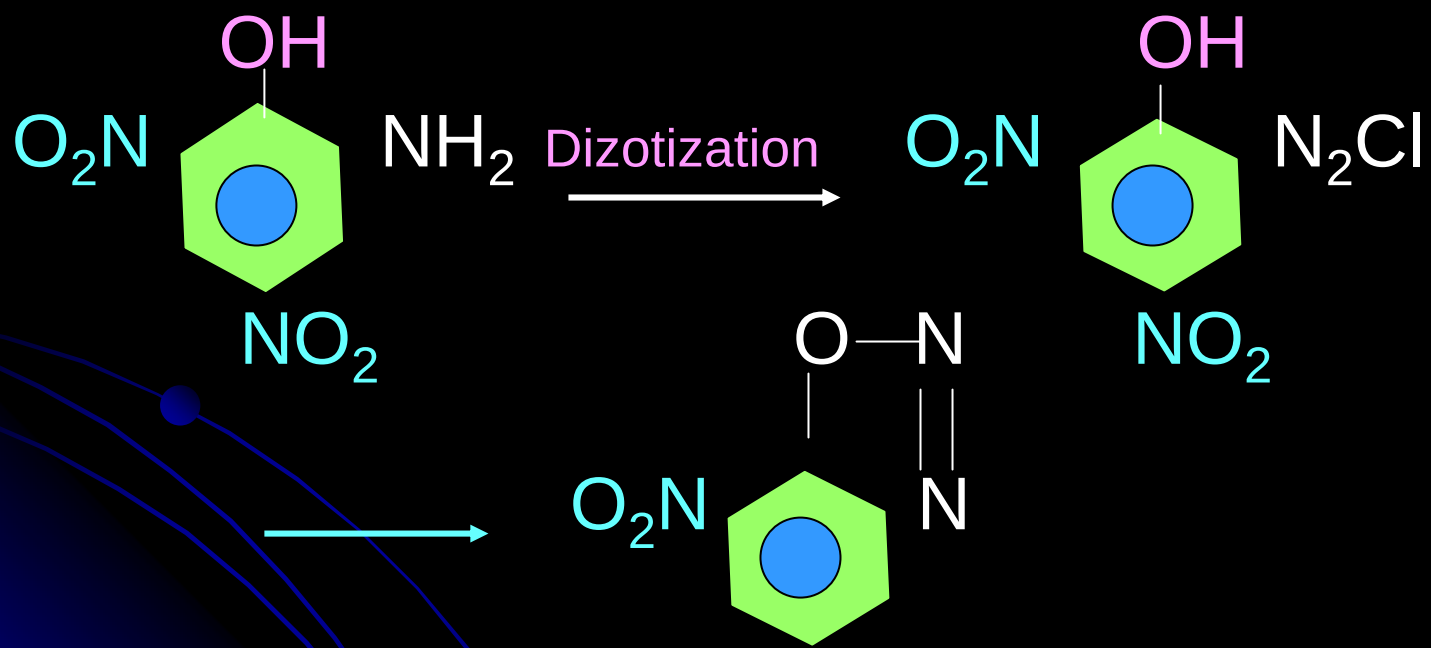
Primary or initiating explosives
or detonators Diazo dinitro phenol(DDNP)

- DDNP is prepared by diazotization of picramic acid



Primary or initiating explosives or detonators 3)DDNP (diazo dinitro phenol)

- Diazo dinitro phenol (DDNP) is prepared by diazotization of picramic acid



Primary or initiating explosives or detonators **4) Tetracene [$C_2H_7N_7O$]**

- low initiating primary explosive.
  - ignites easily
  - high heat of explosion
- produces large volume of gas.
  - Not used by military.
  - Used as a detonator.

LOW EXPLOSIVES

- **BLACK POWDER (OR GUN POWDER)**

- **SMOKELESS POWDER OR NITROCELLULOSE**

LOW EXPLOSIVES

BLACK POWDER (OR GUN POWDER)

Gun powder is a mixture of

10% Sulphur, 15%charcoal & 75% KNO_3

$$10KNO_3 + 3S + 8C \longrightarrow 3K_2SO_4 + 2K_2CO_3 + 6CO_2 + 5N_2 \uparrow$$

LOW EXPLOSIVES
BLACK POWDER (OR GUN POWDER)

- **Excess of S and C lead to slower reaction and more gases:**

$$4K_2CO_3 + 7S \longrightarrow K_2SO_4 + 3K_2S_2 + 4CO_2 \uparrow$$

$$4K_2SO_4 + 7C \longrightarrow K_2CO_3 + 2K_2S_2 + 5CO_2 \uparrow$$

LOW EXPLOSIVES
BLACK POWDER (OR GUN POWDER)

- Uses:
- for blasting down of coal
- Time in delay-fuses
- In shells, igniters and primer assemblies for
- Propellants, practice bombs,

LOW EXPLOSIVES
2. SMOKELESS POWDER OR NITROCELLULOSE

- A mixture of **Cellulose+ sulphuric acid + nitric acid** is dissolved in

- a mixture of **ether and alcohol** and then
- the solvent is Evaporated when

- a Jelly like precipitate left.
- **Stabilizer like diphenylamine**
- is added to it and…..

LOW EXPLOSIVES
2. SMOKELESS POWDER OR NITROCELLULOSE

- The product is pressed into **cylindrical rods**
- It is called Smokeless powder because it
- produces CO_2, CO, N_2, water vapour and
- no smoke.

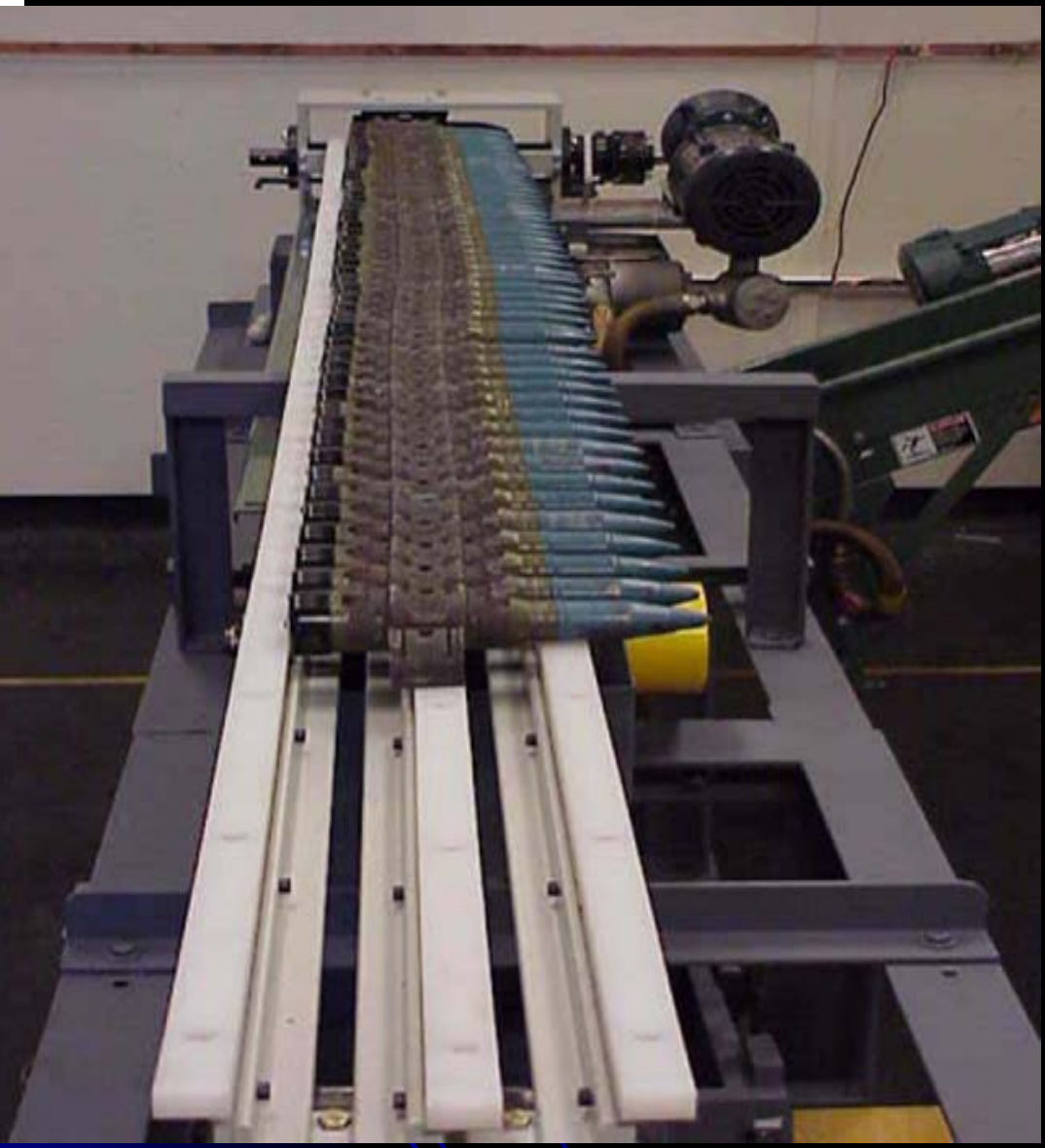
HIGH EXPLOSIVES

1.Single compound explosives

2. BINARY EXPLOSIVES

3.Plastic explosive

4 .dynamites



HIGH EXPLOSIVES

1.Single compound explosives

i) Ammonium nitrate

ii) TNT 2,4,6 tri nitro toulene

iii) PETN pentaerythritol tetranitrate

iv) RDX or Cyclonite (or cyclotrimethylene trinitroamine)

v) Picric acid (or trinitrophenol)

vi) Tetryl (or nitroaryl nitroamine)

HIGH EXPLOSIVES Single compound explosives

i) Ammonium nitrate

- it is very stable, non-toxic, cheap and low brisance value.

- About half powerful as TNT.
- Used to prepare binary compounds

- It has the +ve oxygen balance.
- On heating gives N_2, NO_2 & N_2O.

HIGH EXPLOSIVES Single compound explosives

i) Ammonium nitrate

- Ammonium nitrate is dangerous to store
- near any inflammable material.

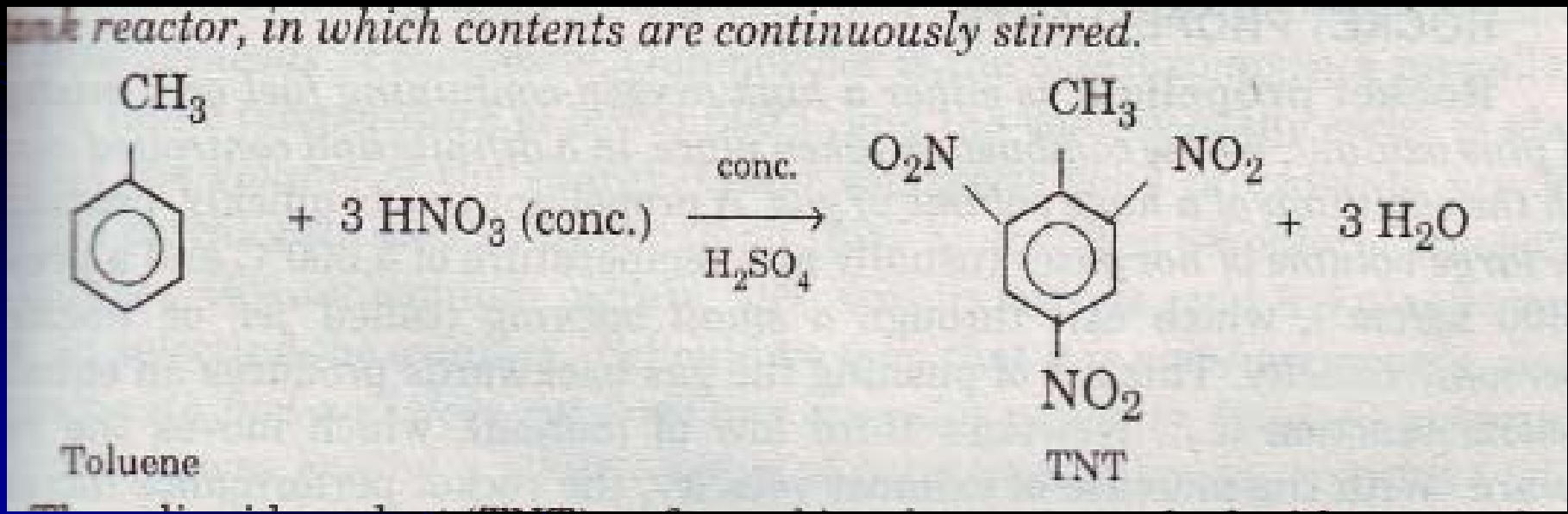
- It cannot be used with Copper or brass.
- Because with copper it forms

- tetraamino cupric nitrate,
- which detonates easily

High explosives Single compound..

ii) 2 4 6 TRI NITRO TOULENE

- High explosive made by nitrating **toluene** using
- a mixture of conc. HNO_3 and conc. H_2SO_4
- in 1:1 ratio in a tank reactor
- with constant stirring.



High explosives Single compound..
ii) 2 4 6 TRI NITRO TOULENE

- then the liquid TNT is
- washed with ammoniacal solution of
- Na_2SO_4 and cold water-
  - crystals of TNT are
    - Filtered
    - purified
    - dried &
    - packed.

High explosives Single compound..

ii) 2 4 6 TRI NITRO TOULENE

- Low melting point (81^0C).

- Decomposition reaction:

$$TNT \longrightarrow 3.5CO + 3.5\ C + 2.5\ H_2O + 1.5\ N_2 + 190\ kcal$$

High explosives Single compound..
ii) 2 4 6 TRI NITRO TOULENE

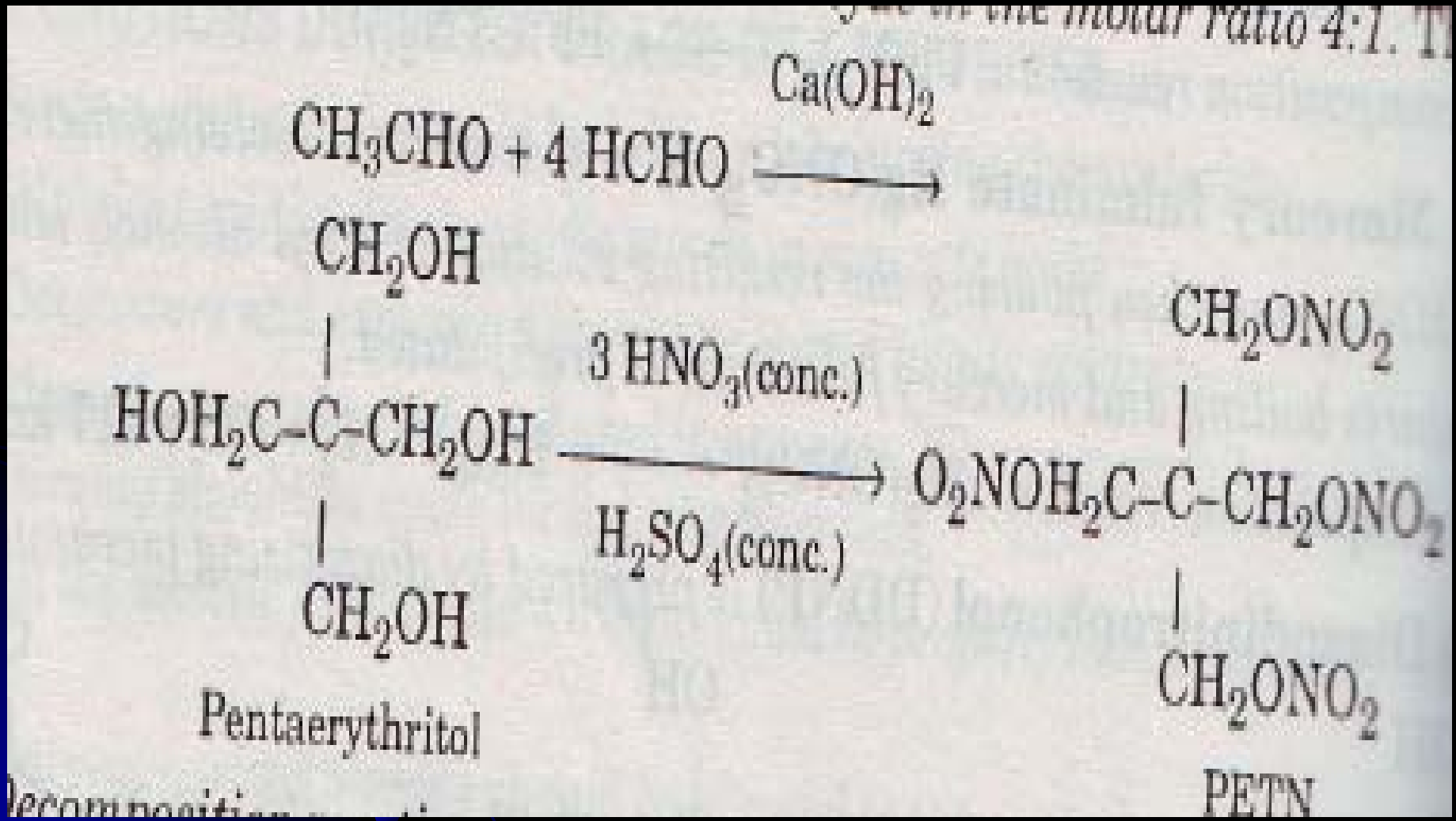
Most widely used

- for shell-firing and
- under water explosions and
- for loading containers.

Important for military use:

- Non-hygroscopic
  - Violent disruptive explosive
- It does’nt react with metals.

PETN (penta erythritol tetra nitrate)

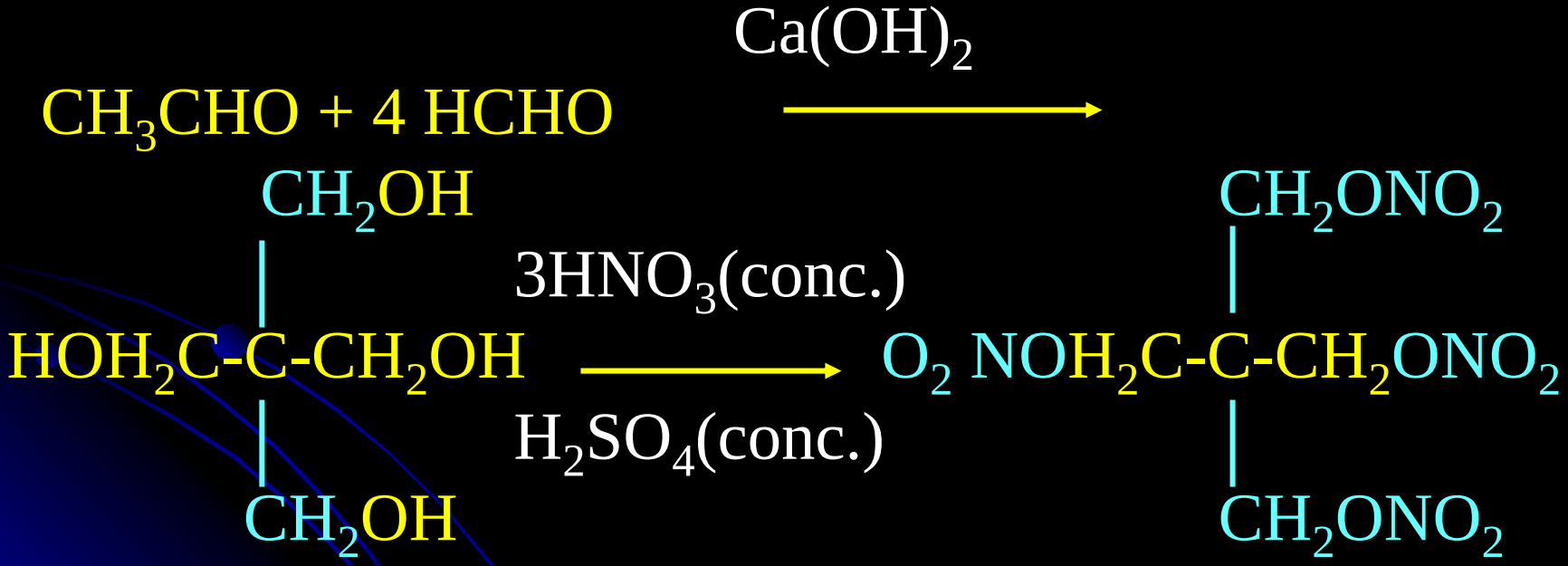


High explosives Single compound..
iii) PETN (pentaerythritol tetranitrate)

- An extremely powerful, sensitive and
  - standard military explosive.
- It is prepared by Cannizaro reaction
- between formaldehyde and acetaldehyde
  - in the molar ratio 4:1

High explosives Single compound..
iii) PETN (pentaerythritol tetranitrate)

- It is prepared by **Cannizaro reaction**
- between **formaldehyde and acetaldehyde in the**
- **molar ratio 4:1**



Penta erythritol **PETN**

High explosives Single compound..
iii) PETN (pentaerythritol tetranitrate)

- **Decomposition reaction:**

$$C(CH_2ONO_2)_4 \longrightarrow 2CO + 3CO_2 + 4H_2O + 2N_2 + 180\ kcal$$

PETN

(penta erythritol tetra nitrate)

- **It is more powerful**
- **Sensitive**
- **Used in military purposes**

High explo… Single.. iv) RDX (cyclonite) cyclotrimethylene trinitroamine

- It is more sensitive but less toxic than TNT
- It is powerful explosive
- Became prominent in world war-II
- Prepared by treating hexamethylene tetraamine with nitric acid:

High explosives Single compound..
iv) RDX (cyclonite)

- Prepared by treating hexamethylene tetraamine with nitric acid:

$(CH_2)_6 N_4 + 4 HNO_3 \longrightarrow (CH_2NNO_2)_3 + NH_4NO_3 + 3HCHO$

hexamethylene tetraamine

RDX

cyclotrimethylene trinitroamine

formaldehyde

High explosives Single compound..
V) PICRIC ACID (or Trinitrophenol)

- is a high explosive .
- largely replaced by TNT because
- it reacts with metals and give
- PICRATES which is shock sensitive.

High explosives Single compound..

VI) TETRYL (or nitroaryl nitroamine)

- used as a booster in
- binary explosives otherwise
  - abandoned.

2.Binary explosive

Consists of mixture of TNT with other explosives.

1. **Amatol**
2. **Pentolite**
3. **Tetrytol**
4. **Tropex**
5. **Titronal**

2.Binary explosive **AMATOL**

- 80 : 20 & 50 : 50 mixtures of
- TNT& ammonium nitrate.
- Gives white smoke, used as high explosive.
- This is known as AMATOL.
- Strength equal to TNT.
- Disadvantage: hygroscopic

2.Binary explosive

2. Pentolite

(a mixture of TNT and PETN 50% each).

3. Tetrytol

(a mixture of TNT 30% and tetryl 70%).

2.Binary explosive

4.Tropex

(a mixture of TNT 40% , 40% RDX and 20% Al powder).

5.Titronal

(a mixture of TNT 80% and 20% Al powder).

3.PLASTIC EXPLOSIVE

- These are the combinations of
- explosives, in plastic state.
- These can be hand moulded,
- press loaded into
- various shapes without any serious risk.

3.PLASTIC EXPLOSIVE

- A high explosive like
- PETN (for destructive power) +
- wax or oil(to make less sensitive and plastic),
- moulded into sheets or putty like masses

.....

3.PLASTIC EXPLOSIVE

- moulded into sheets or putty like masses
- which can be cut into pieces and
- fixed to metal parts by an adhesive
- for engineering applications.
- These are used in industrial and
- military purposes.

4 .dynamites

- It mainly consists of nitroglycerine (NG). NG is an oily liquid
- This is detonated by
- pressure, shock or spontaneously
- above 50^0C

$$4C_3H_5(NO_3)_3 \longrightarrow 10H_2O + 6N_2 + 12CO_2 + O_2$$

4 .dynamites

- The explosion is sudden and
- dangerous in handling
- impossible to transport and so
- it is mixed with an inert absorbent e.g.
  - wood pulp,
  - starch meal,
  - saw dust etc.
- It pulverizes rocks into pieces

4 .dynamites

1. STRAIT CHAIN DYNAMITES

2.BLASTING DYNAMITES

3.GUN COTTON

4.CORDITE

Dynamites
1. STRAIT CHAIN DYNAMITES

- **15% -60% nitroglycerine (NG) in**
- **wood meal + sodium nitrate as oxidizing agent**

- **Uses:**
- **for blasting hard rocks,**
- **coal & other minerals and**
- **demolitions.**

Dynamites
2.Blasting dynamites

- are nitroglycerine (NG) is partly gelatinized by nitro cotton [or colloidal cotton].

Composition:

- 91.5%NG, 8% nitro cotton, 0.5 %$CaCO_3$
- These are
- jelly like substances
- Very powerful, do not flow.

Dynamites
2.Blasting dynamites

Can be used:

- under water where high loading density is needed.

- In submarine blasting,

- Deep well shooting etc.

Dynamites
3.Gun cotton

- When cotton is kept in cool mixture of conc. nitric acid, and conc. sulphuric acid for ½ an hour

- $C_6H_7O_2(OH)_3 + 3HNO_3 \longrightarrow C_6H_7O_2(NO_3)_3 + 3H_2O$

Dynamites
3.Gun cotton

- Gun cotton explodes very rapidly
- (in a few ten thousandth of a second)

- Used in torpedoes and submarine mines.

- It is used in rifles or artillery shells.

Dynamites
4.cordite

- a form of smokeless powder made by dissolving
  - gun cotton(65parts) +
  - Nitroglycerine (30parts) +
  - petroleum jelly

  Or
  - Vaseline (5parts) in acetone

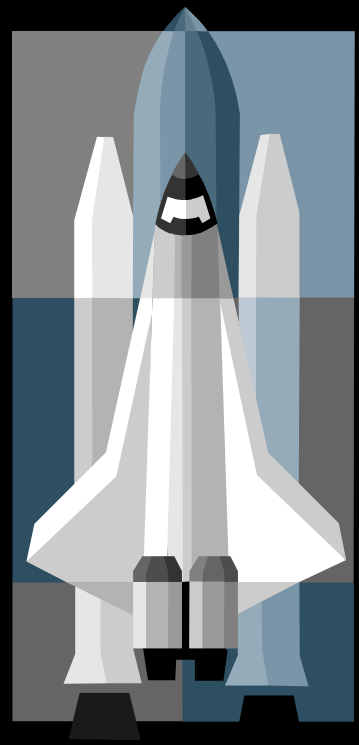
Dynamites
4.cordite

- This paste is rolled &
- cut into pieces of different dimensions.
- The Vaseline acts as coolant &stabilizer
- When acetone evaporates the cordite remains.

Dynamites
4.cordite

- The gun cotton slows down the
- explosive reaction of Nitroglycerine.
- This makes cordite as
- an excellent propellant
- Used in naval guns.

Rocket propellants



Rocket propellants

- Rocket propellants is either a
- high oxygen containing fuel plus oxidant,
- whose combustion taken place,
- in a definite and controlled manner with
- the evolution of a huge volume of gas.

Rocket propellants

- Propellants are burnt in combustion chamber & hot gases

  (about 3000^0c - 300kg/cm^2)

- Which escape through a
- small opening called ‘jet’ or ‘nozzle’

- at supersonic velocity (very high speed).

Rocket propellants

- This action of pumping the gases downwards produces

- an equal & opposite reaction
- (c.f. Newton's third law of motion.)

- Which moves the rocket upward.

Rocket propellants

Rockets are used for:

1. Pyrotechnic effect signaling,
2. Carrying a life,
3. Hurling explosives at an enemy,
4. putting space capsule into orbit. etc.

Rocket propellants

Characteristics of a good propellant:

It should have:

1) high specific impulse.

Specific impulse is the thrust delivered divided by the rate of propellant burnt (fuel plus oxidant).

Rocket propellants

2) It should produce low molecular weight products (like CO,CO_2, and N_2).

3) It should burn at slow and steady rate.

4) It should have low ignition delay i.e. the time taken to catch fire.

5) high density 6) stability.

Rocket propellants

7) readily ignitable

8) safe to handle and store,

9) non-corrosive and non-hygroscopic

10) no solid residue after ignition.

11) no toxic products.

12) high temperature on combustion

Rocket propellants-**Specific impulse**

- **Specific impulse** ***is the thrust in kg per second per kg of fuel burnt.***

- Thrust is the main force responsible for the push.

- The value of thrust or propulsive force due to momentum is given by:

Rocket propellants-**Specific impulse**

Specific impulse –

it is obtained when unit mass of fuel is burnt

$$F = \frac{m}{g} v + (P_e - P_a) A_e$$

where F = thrust(kg/m/kg); m = mass flow

g = acceleration due to gravity ((9.81 m/s^2) ;

v = exhaust velocity (m/s)

P_e = exit pressure (kg/m^2)

P_a=ambient gas pressure (kg/m^2)

A_e = nozzle exit area (m^2)

CLASSIFICATION OF propellants

- **CLASSIFICATION OF PROPELLANTS**
- 1.solid propellant
  2.liquid propellants
- 1. Solid propellants: may be *Homogenous or composite*

CLASSIFICATION OF Homogeneous solid propellant.

- **Homogeneous solid propellant.**
- when a solid propellant or a mixture of propellants is thoroughly mixed in a colloidal state.

1. Single based propellants
2. Double base propellants

CLASSIFICATION OF Homogeneous solid propellant.

- Single based propellants: When a single propellants is mixed.
- ex: nitro cellulose in nitro glycerine
- also known as gun cotton or
- Smokeless powder or nitrocellulose

CLASSIFICATION OF Homogeneous solid propellant.

Double base propellants:

solid propellant with two materials

e.g. **Ballisite containing nitrocellulose + nitroglycerine**

Cordite: 65% nitrocellulose + 30% nitroglycerine + 5% petroleum jelly as plasticizer

These give

a flame temperature upto 2700^0C and

1500 times volume of the gases

CLASSIFICATION
Heterogeneous or composite:

- When an oxidizing agent is dispersed in a fuel mass , the solid propellant is heterogeneous in nature

Example :

- Gun powder or gun cotton gives
- a flame temp. of 800 - 1,500^0 C
- And 400 times volume of the gases.

CLASSIFICATION
Heterogeneous or composite:

- A mixture of any of the following
  - **75% perchlorate + 25% asphalt oil;**
  - **80% ammonium perchlorate + 20% resin binder;**
  - **46% ammonium picrate + 48% sodium nitrate + 8% plastic resin binder.**

CLASSIFICATION
Heterogeneous or composite*:*

The oxidizer should be

- non-hygroscopic
- stable in contact i.e. non-corrosive
- Easy & safe to store
- More economical

CLASSIFICATION

2 LIQUID PROPELLANTS

- These are more advantageous,
- more versatile and
- the engines can be checked and calibrated more easily.
- But the engines are quite delicate and cannot withstand any rough handling.

Two types

1. Mono propellants
2. Bi propellants

2 LIQUID PROPELLANTS

1.Mono propellants

- These have fuel & oxidizer in the same molecule or in a solution containing both these. Example :
  - hydrogen peroxide,
  - nitromethane,
  - ethylene dioxide,
  - hydrazine,
  - propyl nitrate etc.

2 LIQUID PROPELLANTS

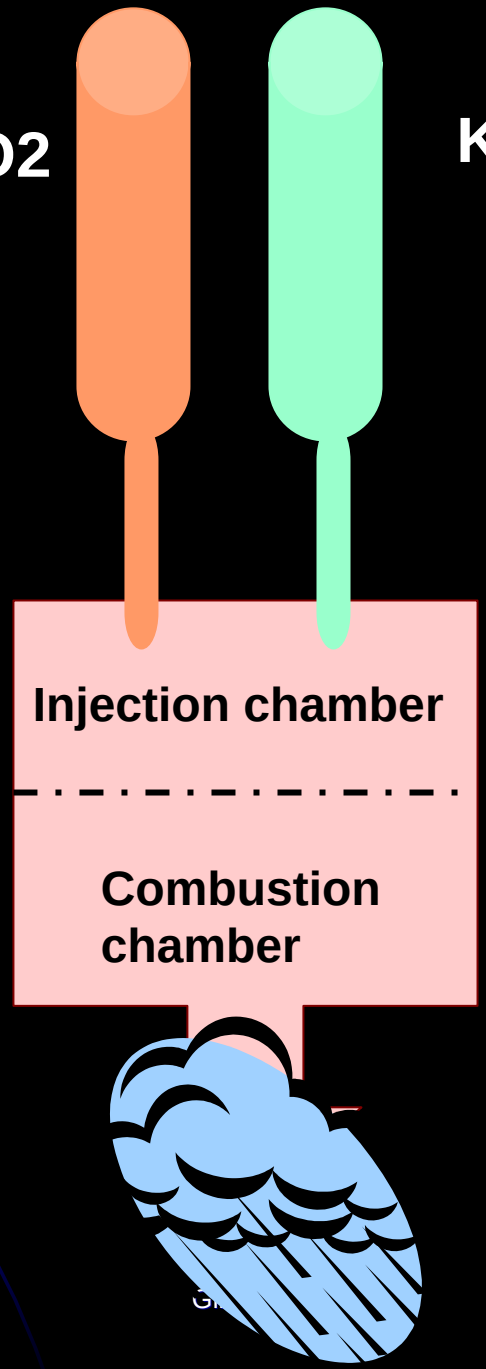
1.Mono propellants

- These have fuel & oxidizer in the same molecule or
- in a solution containing both these.

- Mono propellants must be safe to store and
- should burn smoothly

Liquid O2

Kerosine



$C_{12}H_{26} + 18.5 + O_2$

$12CO_2 + 13H_2O$

Use of bipropellant in a rocket

LIQUID PROPELLANTS
2.Bipropellants

- Here liquid fuel & oxidizer are kept separately,
- are injected in the chamber separately.

Commonly used fuels are :

- liquid H_2
- hydrazine,
- ethyl alcohol,
- aniline and
- kerosene oil.

LIQUID PROPELLANTS
2.Bipropellants

- Commonly used fuels are :
- liquid H_2
- ethyl alcohol,
- hydrazine,
- aniline and
- kerosene oil.
- The common oxidizers are:
- liquid O_2, O_3
- H_2O_2,
- fuming HNO_3, and
- liquid F_2.

LIQUID PROPELLANTS
2.Bipropellants

- liquid oxygen is non-toxic safe and good but to be kept under pressure.
- Ozone is very powerful but quite toxic and can explode at high concentrations.
- Liquid fluorine is very good oxidizing agent but volatile, toxic, corrosive and very difficult to store and handle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