

## CHEMICAL TECHNOLOGY

### (1) Inorganic chemical Industries

- Sulphur & Sulphuric Acid Industry ( $S + H_2SO_4 \rightarrow H_2S + SO_2$ )
- Nitrogen Industry ( $NH_3, HNO_3, NH_4Cl, NH_4NO_3$ )
- Phosphorus Industry ( $P_4, H_3PO_4, SSP, TSP$ )
- Potassium Industry
  
- Electrochemical Industry (Chlor-Alkali Industry).
  - [ $Cl_2, NaOH$  (Caustic Soda),  $NaHCO_3, Na_2CO_3$ ].
  
- Fuel & Industrial Gases.

### (2) Natural Product Industries

- Edible & Essential oil.
- Soaps & detergents & glycerine.
- Carbohydrates & fermentation Industry.
- Pulp & paper Industry.
- Petroleum Industry.

### (3) Synthetic Organic Chemicals / Petrochemicals.

- (i) SOC produced from  $C_1$  compounds. ( $CH_4$ )
- (ii) SOC " "  $C_2$  compounds. ( $C_2H_6, C_2H_2, C_2H_4$ ).
- (iii) SOC produced from  $C_3$  compounds.
- (iv) SOC " "  $C_4$  compounds. (Butane)
- (v) SOC " " aromatic compounds.

### 4) Polymerisation Industry :-

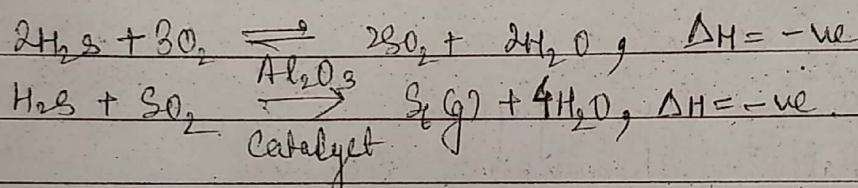
- Plastics → Thermoplastics & thermosetting
- Elastomers
- Fibres
  - Acrylic fibres.
  - Polyamide
  - Polyester
  - Cellulose fibres.

## Part I: INORGANIC

### (1) Sulphur & Sulphur Industries:-

- Sulphur is produced by Iron pyrite, Copper pyrite ("FINNISH PROCESS")
- S produced from Salt domes → "Frasch Process"
- Oxidation - Reduction of  $H_2S \rightarrow$  "Claus Process"

### Claus Process:-



### Uses of Sulphur:-

- Major use in HgS production.
- In rubber vulcanisation agent
- In Insecticide, Fungicide & in Skin disease.
- Gun powder, Fireworks.

### $H_2SO_4$ :-

- Completely miscible with  $H_2O$  with large heat of soln & if its composition is 93% conc then its called Rectified Oil of Vitriol.
- Composition of HgS is 77%, called as Brown Oil of Vitriol.

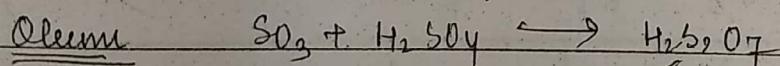
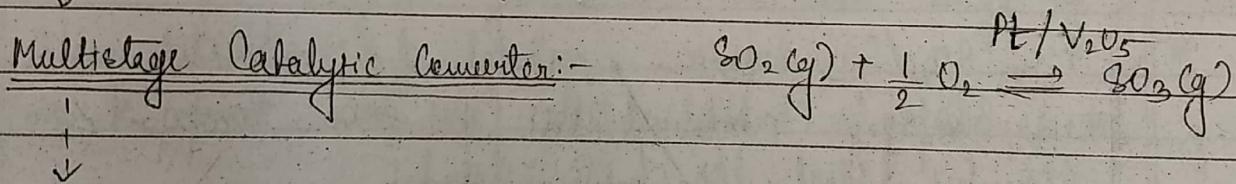
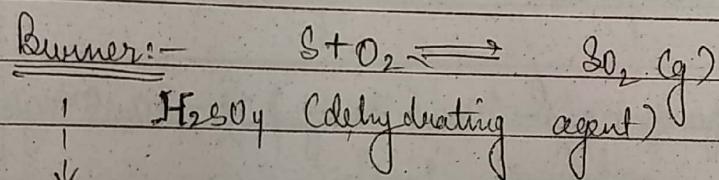
When composition 33.3% , called Battery Acid.

Raw Material :- Sulphur & Air.

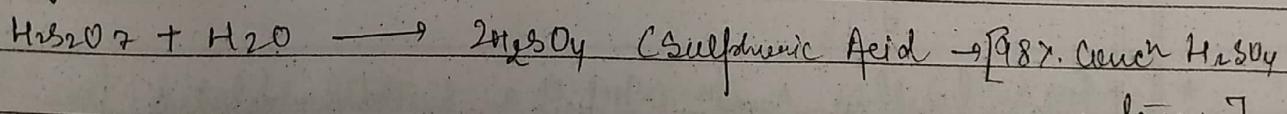
### Methods of Production :-

- (1) Lead Chamber Process (conc  $H_2SO_4$  < 80%)
- (2) Contact process (conc  $H_2SO_4$  = 98%)
- (3) Double contact double absorption process (conc > 99.5%)  
(DCDA)

### DCDA process :-



### Oleum absorption Tower



Preciously Pt was used as a catalyst and its activity is high but now  $N_2O_5$  is used as a catalyst because it is relatively immune to poison.

## Advantage & disadvantage of $V_2O_5$ :

- Adv → Relatively immune to poison.
- Required in very less amount (10kg in production of 1 ton of HgO).
- less initial investment.
- low Replacement cost. (5%).

- Dis → low Activity.
- Must use dilute  $Fe_2$  input (7% to 10%).
- larger converter used.
- Require high  $O_2/SO_2$  ratio to give economic conversion.

### # 20. Ques:-

In a mixture of  $HgO$  &  $SO_3$  (100 kg),  $SO_3$  (20 kg)

- # For  $SO_2/SO_3$  service, material of construction will be simply carbon steel for low temp & stainless steel for high temp.
- # The preferred material for construction of storage tanks (98% HgO), stainless steel 316 and stainless steel type 304.
- # For handling pure  $Hg$ , a suitable material for construction is Hastelloy (Nickel based Steel alloy).  $Hg$  is most corrosive acid so mild steel & stainless steel not used.

### Uses of H<sub>3</sub>BO<sub>3</sub>:

- In phosphate fertilizer
- Inorganic chemicals
- In pulp & paper industry
- In synthetic rubber & plastics.

### Fertilizer Industry:-

The production of N<sub>2</sub> fertilizer should be given the highest national priority next only to defence & family planning.

3 major components are necessary in Fertilizers:-

- (i) N<sub>2</sub> → required during early stages of plant growth, to promote development of stems & leaves.
- (ii) P<sub>4</sub> → Used in early growth and accelerates setting & fruit formation in later stage of growth.
- (iii) K → Essential to development of starch of grains & vegetables.

$$\Rightarrow \% \text{N}_2 - \% \text{P}_2\text{O}_5 - \% \text{K}_2\text{O}.$$

Urea: - 46 - 0 - 0.

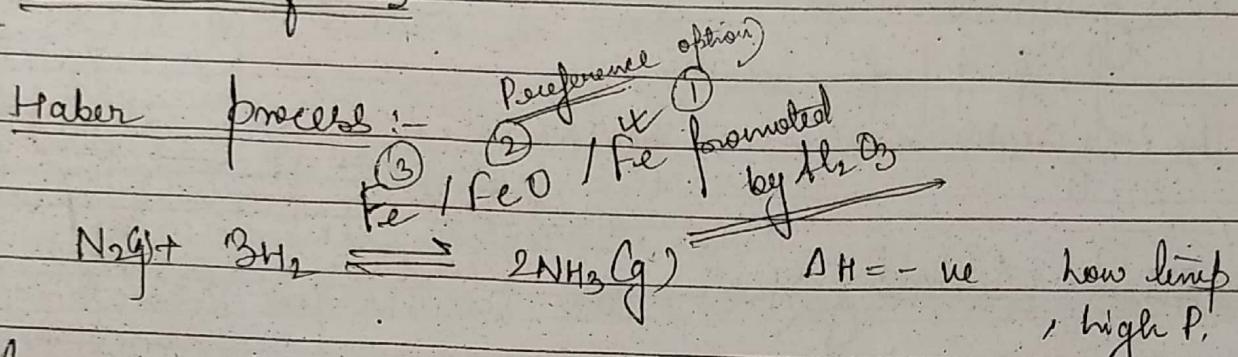
Single Superphosphate: - 0 - 20 - 0. (Used H<sub>3</sub>BO<sub>3</sub>)  
 (SSP) 0 - 30 - 0 (Used HNO<sub>3</sub>)

Triple Superphosphate: - 0 - 50 - 0.  
 (TSP)

## (I) Nitrogen Industries:-

### a) Production of $\text{NH}_3$ :-

→ Haber process :-



→ Source of  $\text{N}_2$  is "air liquefaction process" & source of  $\text{H}_2$  is "Synthesis Gas".

→ End Uses of  $\text{NH}_3$  :-

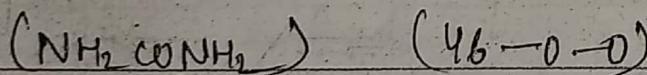
(1) Production of Urea.

(2)  $(\text{NH}_4)_2\text{PO}_4$ .

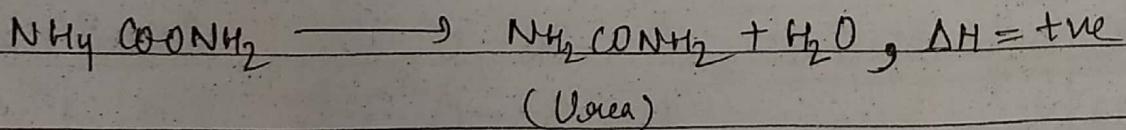
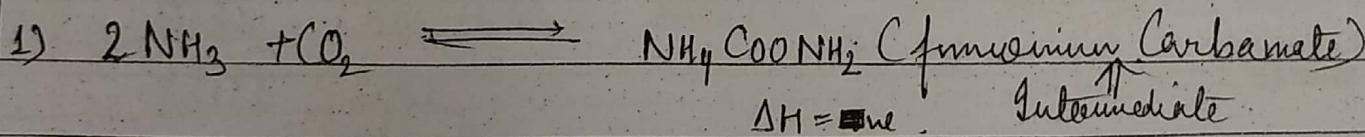
(3)  $(\text{NH}_4)_2\text{NO}_3$

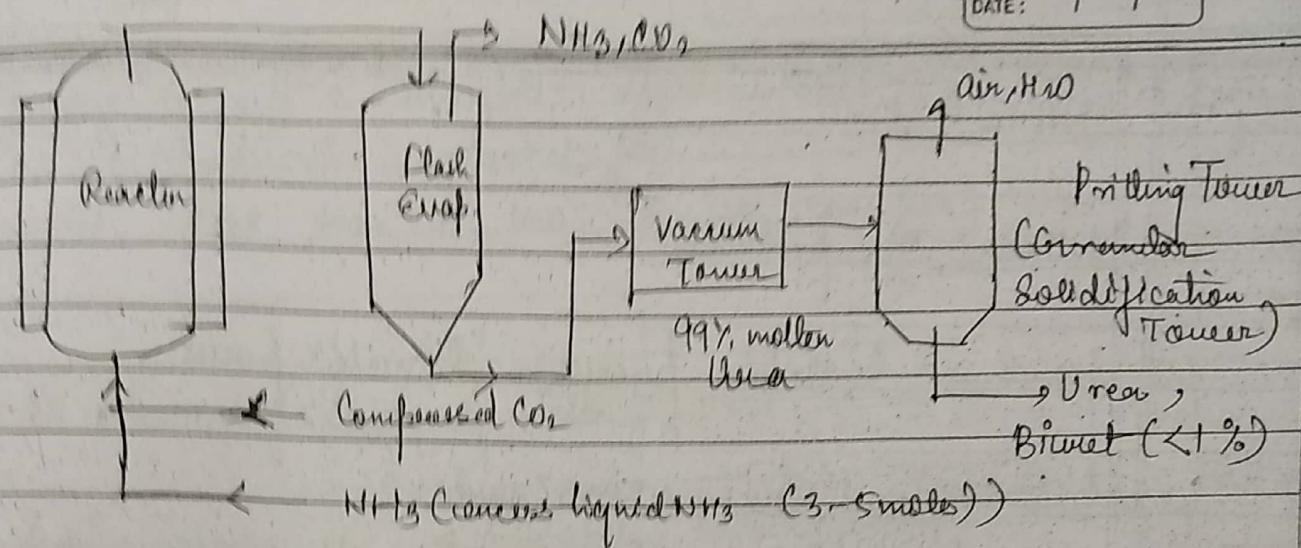
(4)  $(\text{NH}_4)_2\text{SO}_4$ ,  $\text{HNO}_3$ , Acrylonitrile.

b) Urea :-

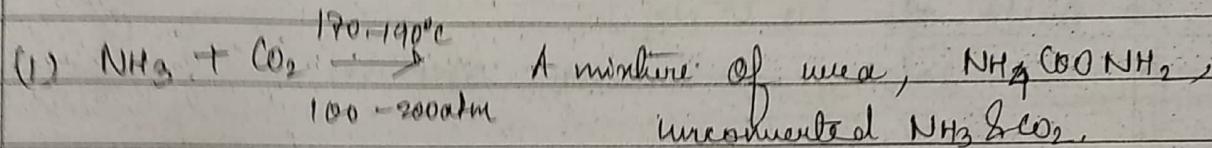


Methods of formation :-





### Steps :-

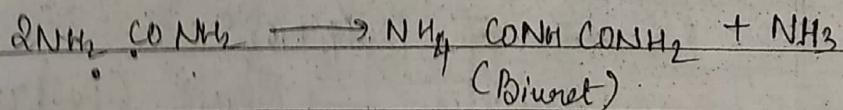


(2) Concentrate  $\text{NH}_4\text{COONH}_2$  from 77% to 99%.

(3) Unreacted  $\text{NH}_3$  &  $\text{CO}_2$  are separated out in flash evaporation.

(4) Molten urea containing <1% water is sprayed into boiling tower. If water is not removed from molten urea within 1-2 secs (Retention time), then urea converts into Biuret.

### Undesirable Side reacn :-



∴  $\text{NH}_2\text{CONH}_2$  is highly corrosive to both ordinary & stainless steel, so we will use Hastelloy and Stainless Steel 821.

\* Urea production rate can be varied as follows:-

(1) Increase with  $\uparrow P$ ;

(2) Increase with temp to a max at  $170-190^\circ\text{C}$  then falls off sharply. Operating Pressure should be above

desorption pressure of  $\text{NH}_2\text{CONH}_2$  ( $180\text{ atm at }190^\circ\text{C}$ )

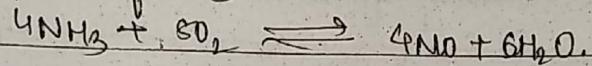


c) Nitric Acid:-

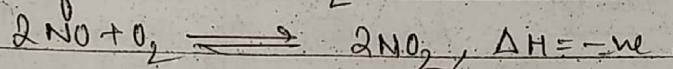
Methods of production :-

(i) Ammonia Oxidation process :- " Ostwald's process "

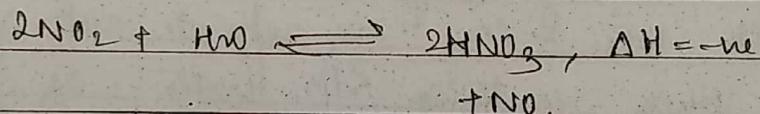
→ Oxidation of  $\text{NH}_3 \rightarrow$  Nitric oxide :-



→ Oxidn of  $\text{NO}$  to  $\text{NO}_2$  :-



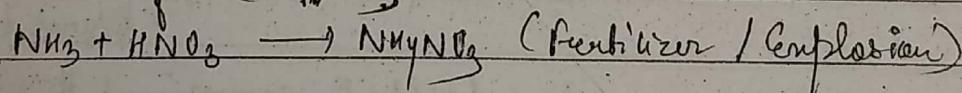
→ Absorption of  $\text{NO}_2$  in water :-



→ Catalyst is Platinum - Rhodium Catalyst.

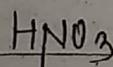
Uses :-

i) Production of  $(\text{NH}_4)_2\text{NO}_3$  :-



$\text{NH}_4\text{NO}_3 + \text{urea} \rightarrow$  Urea - Ammonium Nitrate  
(Popular fertilizer)

2) Production of Adipic acid, Nitrobenzene & Sodium potassium & calcium nitrate.



white fuming  $\text{HNO}_3$

Red fuming  $\text{HNO}_3$

- White fuming  $\text{HNO}_3$  is a storables liquid oxidizer used with kerosene & hydrazine rocket fuel.
- It consist less than 2%  $\text{H}_2\text{O}$  & less than 0.5%  $\text{NO}_2$ .
- Uses:-

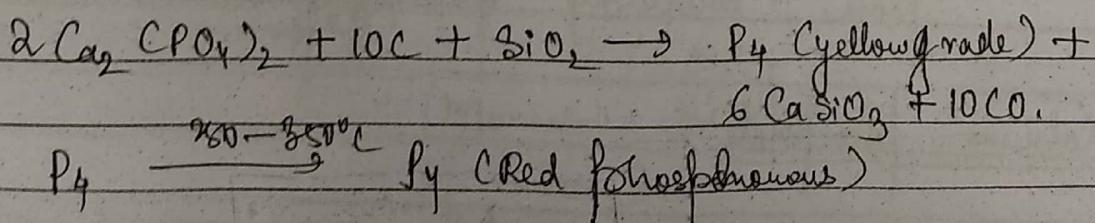
- Used in manufacturing of inter glycine.
- Red fuming  $\text{HNO}_3$  is a storables liquid oxidizer used as a rocket propellant.
- It consist 1-2%  $\text{H}_2\text{O}$  & 13%  $\text{NO}_2$  remaining  $\text{HNO}_3$ .
- Uses:-
- In fertilizer, pharmaceutical, yield aid, explosives.

## II) Phosphorous Industry :-

- Phosphorous in elemental form & its many forms derived from commercial deposit of Phosphate Rock (Fluorapatite)  $\text{Ca}_{10}(\text{PO}_4)_6 \cdot \text{F}_2$ .
- Phosphorous content of rock phosphate is expressed as %  $\text{P}_2\text{O}_5$ . In Trade, it is expressed as Bone phosphate of lime, chemically means Tricalcium phosphate  $\text{Ca}_3(\text{PO}_4)_2$ .

- Chemicals produced :-

↳ Yellow or white phosphorous :-

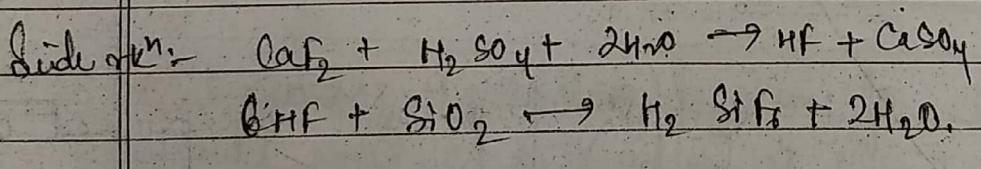
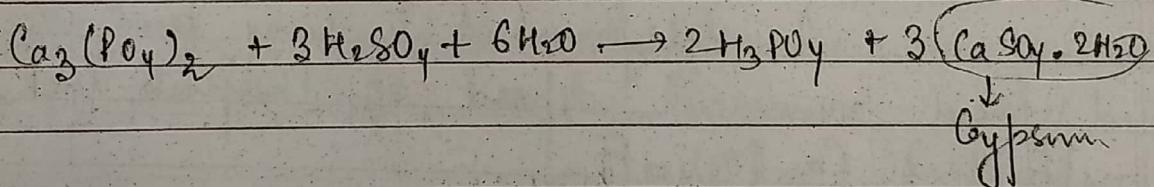


Uses:-

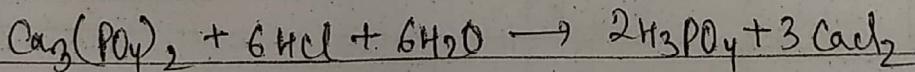
- Major application in production of orthophosphoric acid.
- In matches.
- In food processing.
- In production of phosphorous oxychloride ( $\text{POCl}_3$ ), phosphorous chloride ( $\text{PCl}_3$ ), phosphorous pentoxide
- Phosphoric Acid ( $\text{H}_3\text{PO}_4$ ):

Methode of production:-

- i) wet process
  - (i) Strong  $\text{H}_2\text{SO}_4$  leaching
  - (ii)  $\text{HCl}$  leaching
- ii) Strong  $\text{H}_2\text{SO}_4$  leaching:-



- iii)  $\text{HCl}$  leaching:- (IMI process)  $\rightarrow$  Israel mining Industries.

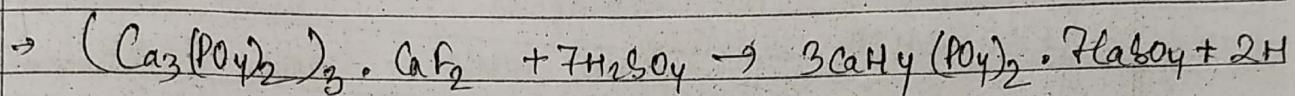


Uses:- In fertilizers, soaps & detergents, in food processing industry.

- Calcium phosphate:-

range stone of low grade.  $\text{Ca}_3(\text{PO}_4)_2$  are made as fertilizer. There are two different grades possible based on method of production from phosphate rock:

## ① Single Imber Phosphate (SSP) →

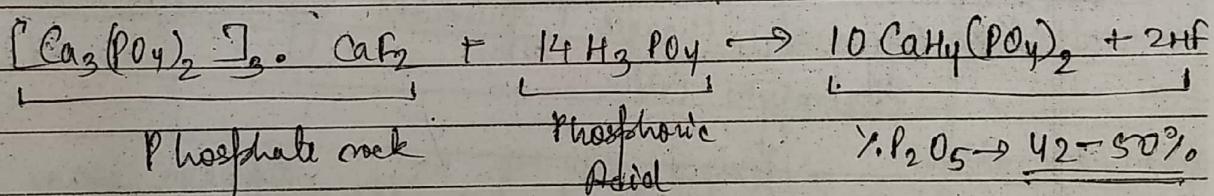


$\rightarrow \text{P}_2\text{O}_5 \rightarrow 16 - 20\%$

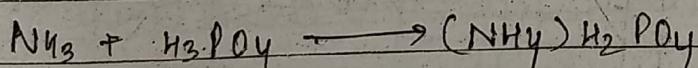
But in case of HgBr if we used  $HNO_3$  then

$$10\% \text{ P}_2\text{O}_5 \rightarrow 30\%$$

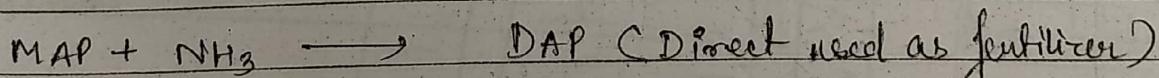
## Tricalcium Super Phosphate (TCP) -



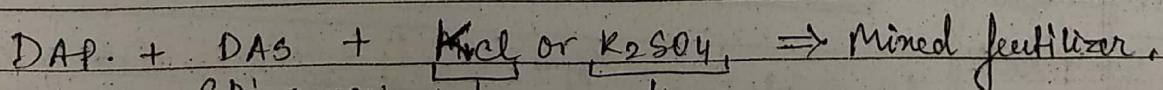
→ Ammonium Phosphate :-



## Mono-ammonium phosphate (MAP)



## Di-ammonium phosphate.



## CDI-ammonium

Sulfate)

Musica

(1 lb. anhydride  
of Potash)

二

Sulphate

of potash)

(3) # Electrochemical Industry (Chlor-Alkali Industry):-

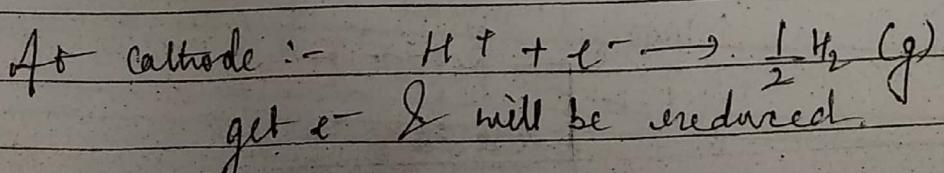
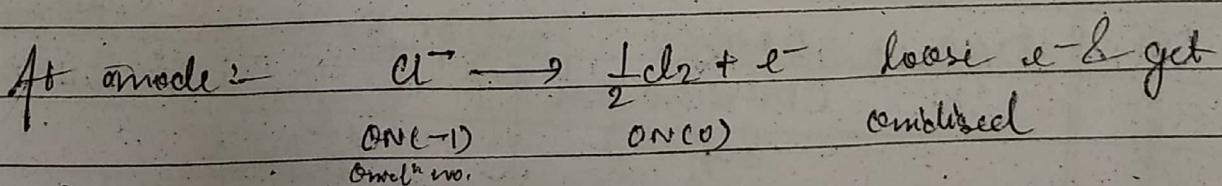
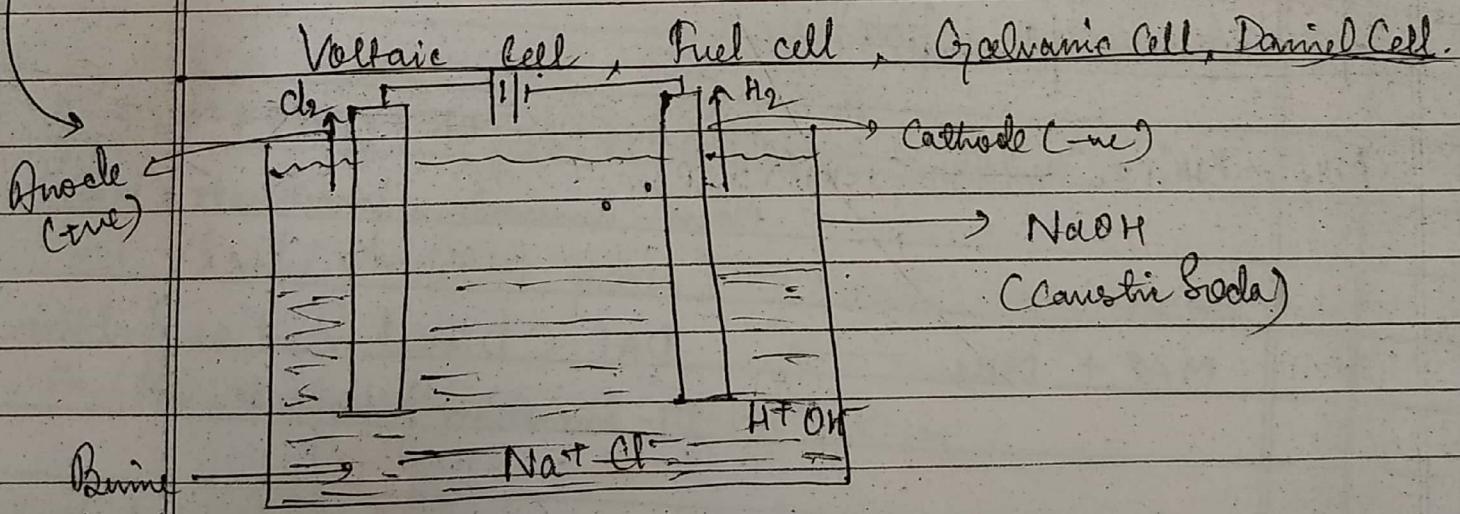
→  $\text{Cl}_2$   
 →  $\text{NaOH}$   
 →  $\text{Na}_2\text{CO}_3$   
 →  $\text{NaHCO}_3$

→  $\text{NaOH}$  :-

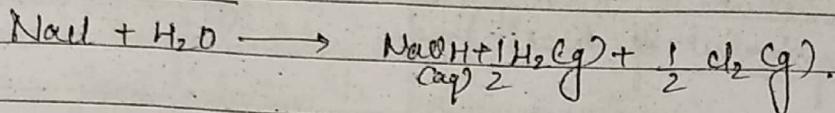
- ① Diaphragm process:-
- ② Membrane process:-
- ③ Mercury process (Castner - Kellner process):-

# Chemical changes produced by electric current:-  
 → Electrolytic Cell.

# Energy produced by chemical changes:-



Overall Rxn:-



(1) Diaphragm

(2) Mercury

(3) Membrane.

→ It produce 10-12% concentrated NaOH & therefore further concentration is req.

→ It produce 70% NaOH directly.

→ It produce 33% concentrated NaOH.

→ Chlorine produced contains O<sub>2</sub>. → Pure Cl<sub>2</sub> produced → Cl<sub>2</sub> produced contains O<sub>2</sub>.

→ less purify Brine can be used. → High purified Brine used. → Intermediate purified brine used.

→ It uses asbestos. → It uses mercury. → Uses membrane

Cell → Energy consumption low (Energy). → Energy consumption very high. → Energy consumption is about 75% of Hg process.

Problem is disposal of asbestos. → Problem is disposal of mercury. → If it is easily disposable but membrane are costly & have short life.

get

Decomposition Efficiency:-

It is similar as conversion efficiency in a chemical reactor.

$$\eta_{DE} = \frac{\text{gm equivalent of NaOH produced} \times 100}{\text{gm equivalent of NaOH fed}}$$

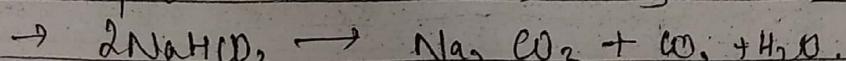
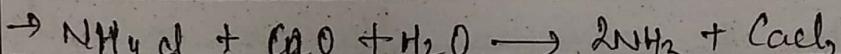
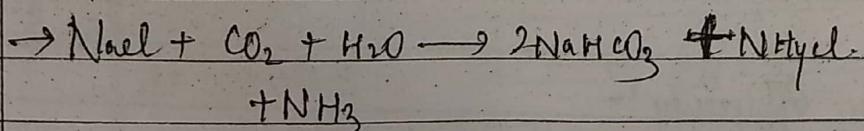
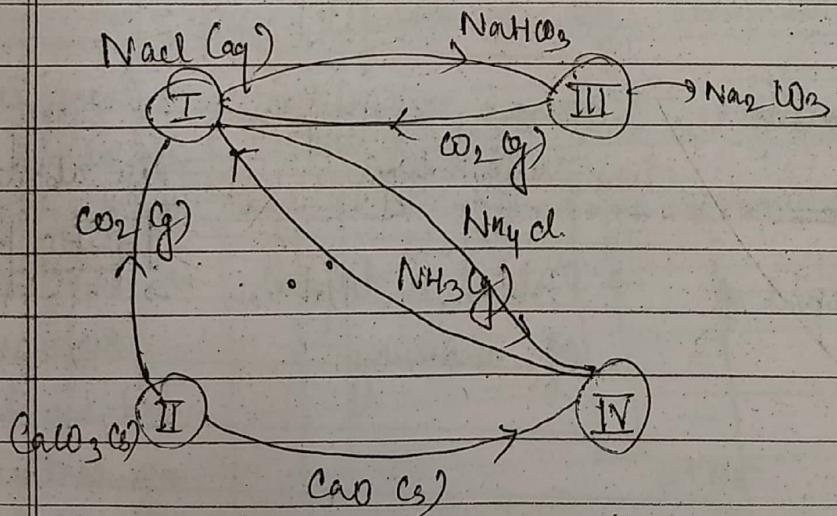
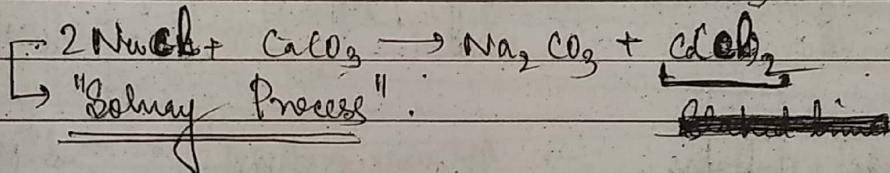
### Uses of NaOH:-

- (1) In soap & detergents
- (2) In textile industry
- (3) In pulp & paper industry
- (4) In dyes.

→  $\text{Na}_2\text{CO}_3$  (Soda Ash):-  $(\text{Ca(OH})_2 \rightarrow \text{Slaked lime})$

↳  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} \rightarrow$  Washing Soda

↳ Basic raw material ( $\text{NaCl}$  &  $\text{CaCO}_3$ )



### Uses of $\text{Na}_2\text{CO}_3$ :

- ① Used in Soap & detergents
- ② In food industry, petroleum refining.

### Uses of $\text{NaHCO}_3$ :

- ① In drugs & medicines, baby powder, food products.
- ② In Beverages.

### (4) FUEL & INDUSTRIAL GASES:-

- Synthetic liquid fuel like gasoline, diesel, fuel oil can be produced by hydrogenation of bituminous oil at high temp & pressure. It is called "BERCEUS PROCESS".
- Catalyst used is "Tim" ( $\text{Sn}$ ) or Molybdenum Sulfide ( $\text{MoS}_2$ ) or Tungsten ( $\text{W}$ ).
- Fischer + By "Fischer Trops process", almost 20% energy demand completed in South Africa.

### Types of Coal:-

- ① Peat (20-25%)
- ② Lignite (25-35%)
- ③ Bituminous (45-85%)
- ④ Anthracite (85-95%).

- Coal is also called "Black gold". It contains C, volatile matter, moisture, ash & Sulphur &  $\text{N}_2$  compounds.
- So methods to find:-

(i) Prominence Analysis

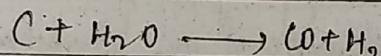
↳ % Ash, % moisture, % Fixed Carbon.

(ii) Ultimate Analysis:-

↳ % N & % S.

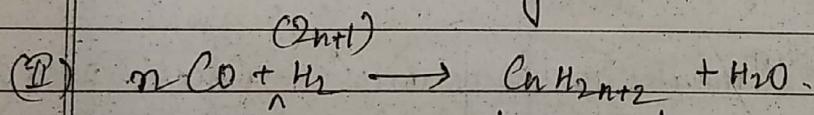
# FISCHER TROPS PROCESS:-

(I) Classification of Coal:-



Synthesis Gas

If ratio of  $CO : H_2$  in synthesis gas is 1:1, then it is Water Gas.

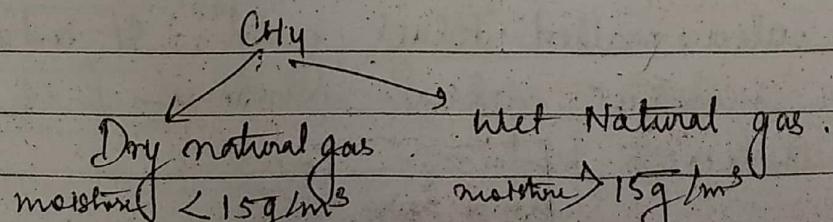


Synthetic fuel (Benzofronic Compounds)

(III) Catalyst used in fisher trops is Cobalt, Nickel or Fe catalyst.

# GASEOUS FUEL:-

→ Mixture of benzofronic HC's in which  $CH_4$  is main constituent.



→ Compressed Natural Gas:- → It has better cold starting properties. Octane number of CNG > 130 & init emission of CO & other HC's is very less. CNG engine have longer life.

→ CNG storage tank are very heavy because it compresses at a high pressure.

→ Liquid Petroleum Gas:- → It is mainly a mixture of propane & butane. 20% propane & 80% butane. Mainly used for cooking purpose & it is non-toxic and cannot support life.

Calorific Value of Natural gas or LPG is 6000-14000 kcal/m<sup>3</sup>. To detect leakage of LPG, we add mercaptans in it.

→ Producer Gas:-

→ It is mainly mixture of CO & N<sub>2</sub> in ratio of 1:2.

→ CO → 20-30% & N<sub>2</sub> → 46-53%.

→ O<sub>2</sub> → 0-3% & H<sub>2</sub> → 11-20%. CO<sub>2</sub> → 4-6%.

→ calorific value of producer gas is 1200-1600 kcal/m<sup>3</sup>. & it is basically used in steel industry for heating purpose.

→ Water Gas:-

→ Main constituents of water gas CO & H<sub>2</sub> in ratio 1:1.

→ CO → 40-43%. CH<sub>4</sub> → 0.1-0.5%. H<sub>2</sub> → 45-50%. N<sub>2</sub> → 3-6%.

→ Water gas is also called Blue gas as it gives blue flame on burning. The calorific value of water gas is 2500-2700 kcal/m<sup>3</sup>.

## → Coke Oven Gas:-

→  $H_2 \rightarrow 50\%$ ,  $CH_4 \rightarrow 30\%$ ,  $CO \rightarrow 7\%$ ,  $CO_2 \rightarrow 3\%$ .

$N_2 \rightarrow 7\%$ . It is used for heating purpose & chemical synthesis. Calorific value of coke oven gas is 4500-8000 kcal  $m^{-3}$ .

## → Oil & Carburetted Gas:- (Water gas and pyrolyzed oil)

→ Calorific value of oil gas is 4000-9000 kcal  $m^{-3}$

Calorific Value :- ( $m^3$ ),

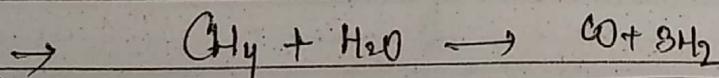
LPG > ENG

Calorific Value :- C / unit mass)

CNG > LPG

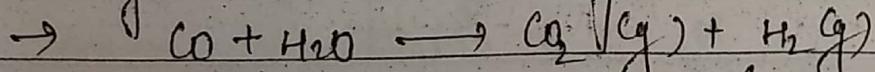
If its not given  $m^{-3}$  or unit mass, then  
CV of furnace oil > WOR, LPG, NGR.

## → Steam Reforming of Methane :- (SMR)



Synthesis Gas

① Performed in Steam Reformer.



② High temp water gas shift reactor

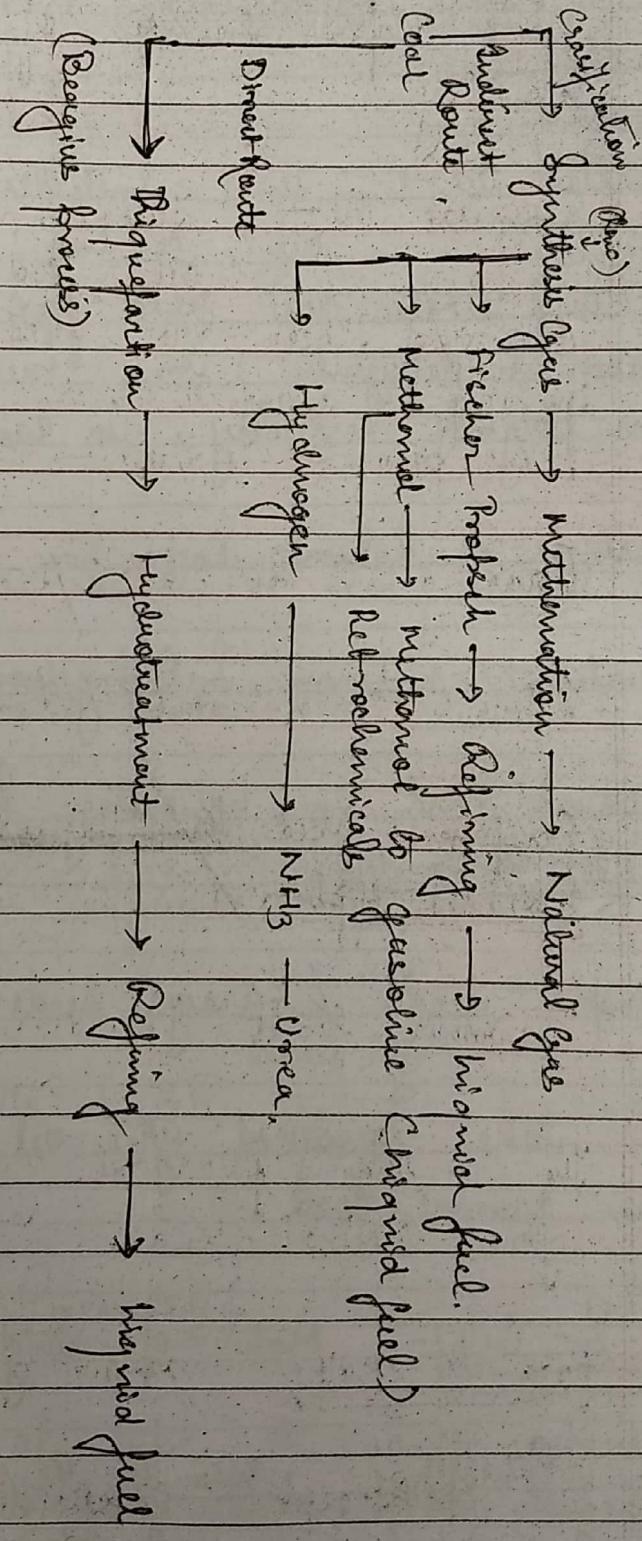
③ Low temp water gas shift reactor

→ Catalyst used in reformer is "Ni" & in

High temp shift reactor is "Random CRN & Ni" & low temp shift reactor is "Cu".

(b) Pressure swing Adsorption (PSA).

Desulphurization of CO<sub>2</sub> → Reformer → Remove CO<sub>2</sub> with help of hot K<sub>2</sub>CO<sub>3</sub> cycle.



## Part 2 : Natural Product Industries

### (B) Edible & Essential Oils →

Edible Oil → Vegetable Oil, are extracted from various seeds. The most common includes Rape seeds, Soya bean, Sunflower seed, Saff-flower seed, mustard oil, Sesame oil, coconut oil. And oil are major source of nutrition for people in country.

Essential Oil → These includes Castor Oil, linseed oil, cool-liver oil, palm oil, Sandalwood oil and these are used for cosmetics, perfumes, in soap & detergents, in medicines, painted varnish, in polymer industry, in sanitation industry.

### Reaching ( Solvent extraction process ) →

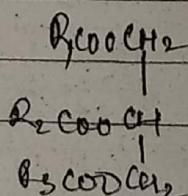
Solvents → n-hexane & Anhydrous Ethanol (Green Solvent)

Equipment used in laboratory to remove oil:-  
Sachet Apparatus.

Jatropha Seeds / Karanja Seeds → Biofuel.

The cake produced after oil extraction is used for animal feed.

Fats & Oils:- Mixture of triglycerides of fatty acids.



When  $R_1, R_2, R_3$  are different → Triglycerides

$R_1 = R_2 = R_3 \rightarrow$  Monoglycerides.

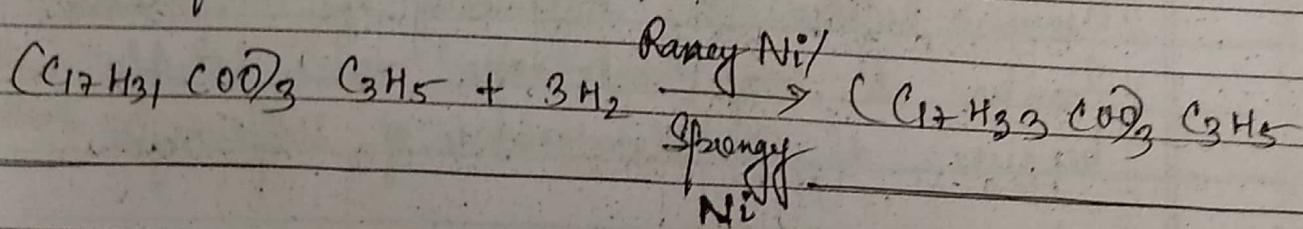
In industrial Biochemistry, oils are liquids and fats are solids at normal temp.

R	Composition	No. of unsaturated bonds	MP	Reactivity with $\text{O}_2$
Stearyl	$\text{C}_{17}\text{H}_{35}$	0	$69^\circ\text{C}$	Nil
Oleic	$\text{C}_{17}\text{H}_{31}$	1	$14^\circ\text{C}$	Faster
Linoleic	$\text{C}_{17}\text{H}_{31}$	2	$-5^\circ\text{C}$	Rapid
Linolenic	$\text{C}_{17}\text{H}_{29}$	3	$-11^\circ\text{C}$	Extremely Rapid

### Hydrogenation of Oil:-

It is a unit process which is used in (i) Oil & Fat Industry

- ① To remove unsaturated bonds.
- ② To raise MP.
- ③ To improve resistance with  $\text{O}_2$ .
- ④ Hydrogenation process improves color, odour & flavour of rancid product.



### SOAP & DETERGENT INDUSTRY:-

"Soap" is compound of type  $\text{R}.\text{COO.M}$  where  $\text{RCOO}$  is fatty group &  $\text{M} \rightarrow$  Alkali element.

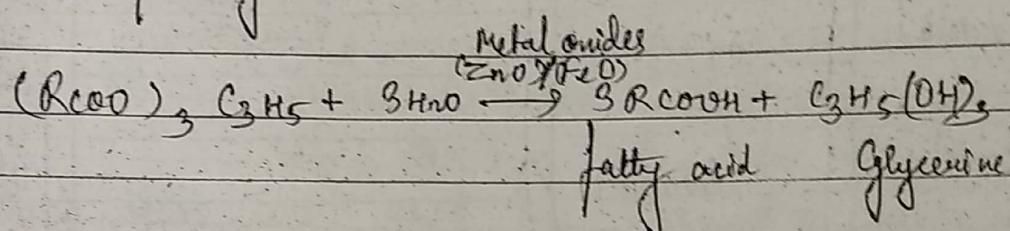
## METHODS OF SOAP PRODUCTION:-

↳ Batch Saponification

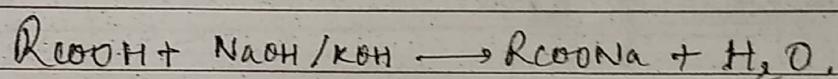
↳ Continuous Hydrolysis & Saponification process.

+ Continuous hydrolysis & Saponification:-

(i) Fat splitting →



(ii) Saponification →



Detergents are synthetic organic chemicals which promote better surface tension lower than soap.

A detergent is a surfactant or a mixture of surfactants with cleansing properties in dilute solution. These substances are usually Alkyl Benzene Sulphonates, a family of compounds that are similar to soap but are more soluble in H<sub>2</sub>O (hard) because of polar nature of sulphonate.

### Soft Water

- Contains Na<sup>+</sup> ion only.
- Taste is salty & sometimes not suitable for drinking.

### Hard water

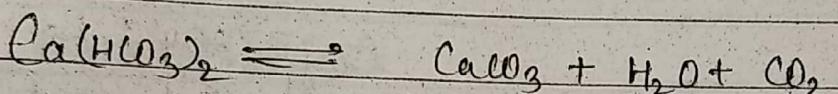
- Contains ions like Ca<sup>2+</sup> & Mg<sup>2+</sup>.
- Taste better to drink than soft H<sub>2</sub>O.

DATE : / /

→ If forms foam with detergents. | → Does not form foam with detergents.

Types of bonds present in  $\text{H}_2\text{O}$  :-

① Temporary hardness :- Is Due to  $\text{HCO}_3^-$  ions present in  $\text{H}_2\text{O}$ .  
This type of hardness can be removed by boiling the  $\text{H}_2\text{O}$ .

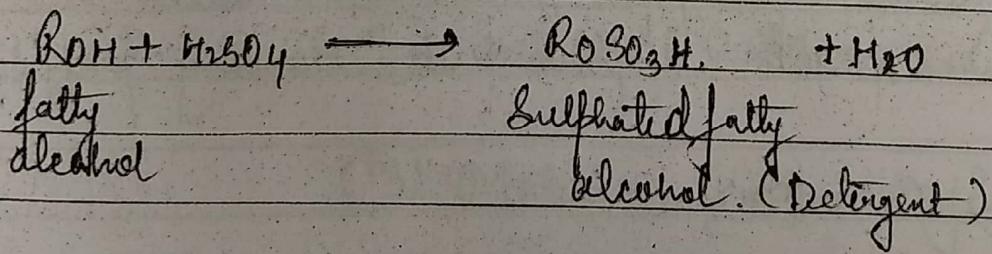


② Permanent hardness :- Is due to calcium & magnesium sulfate & chlorides. This type of hardness can't be eliminated by boiling.

## Types of Detergent :-

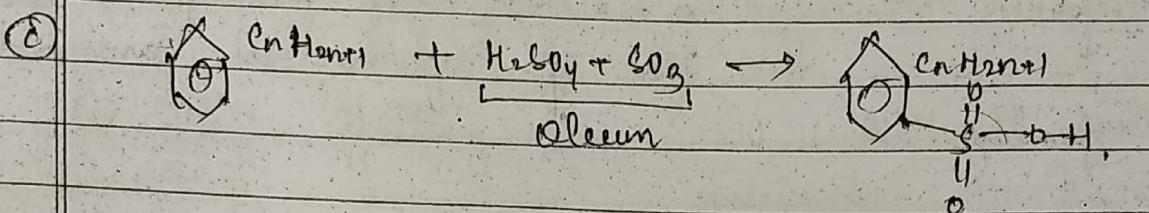
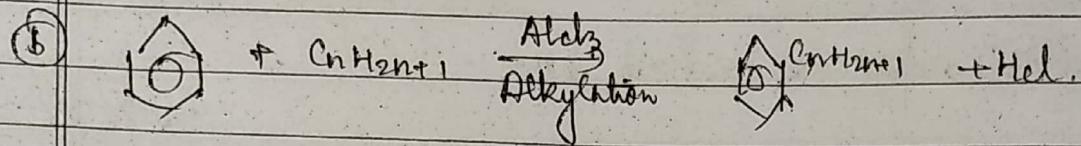
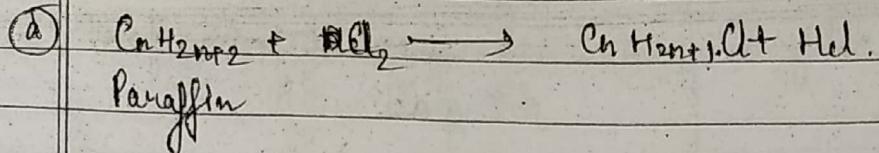
① Anionic : gives  $\text{O}^-$  group in  $\text{H}_2\text{O}$ .

- Catalytic hydrogenation of coconut oil → fatty alcohol.
- Sodium Reduction of coconut oil.



Anionic detergent → "aryl-Alkyl detergent"

### ③ Angly-alkyl Sulphonates :-



Amyl Benzene

Sulfonate (ABBS)

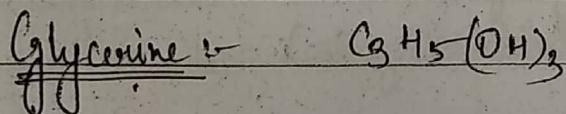
Detergent.

(2) Cationic :- It has no strong detergent property but has germicidal properties.

(3) Non-Ionic :- It has fatty acid amides & such compounds produce less foam.

Detergent Builders :- Zeolites, Sodium tri polyphosphate.

They are chemical compounds that are added to a detergent product to improve its cleaning properties.



Produced by 2 methods :-

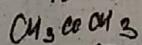
(i) With Soap & Detergent production

(ii) By Synthetic method :-

↓  
Allyl Route

(Epichlorohydrin as intermediate)

(Co-product)



↓  
Acrolein Route

(Acetone as  
by product)

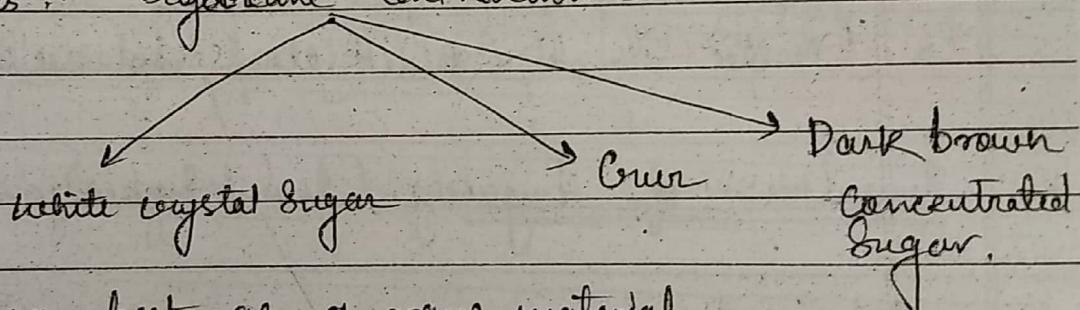
## (CII) Carbohydrates & Fermentation Industry :-

Natural occurring combinations of C, H & O with last two in same ratio as  $\text{H}_2\text{O}$ .

- ① Sucrose (Disaccharides)  $\rightarrow \text{C}_{12}\text{H}_{22}\text{O}_{11}$  (Table sugar ordinary sugar)
- ② Starch  $(\text{C}_6\text{H}_{10}\text{O}_5)_n$
- ③ Starch Derivative :-
  - $\rightarrow$  Dialdehyde Starch
  - $\rightarrow$  Dextrin
  - $\rightarrow$  Starch Phosphate
- ④ Dextrose  $(\text{C}_6\text{H}_{12}\text{O}_6)$
- ⑤ Cellulose  $(\text{C}_6\text{H}_{10}\text{O}_5)_x$ ,  $x \rightarrow 250-1500$

Sucrose : -  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$  MW  $\rightarrow 342$

Raw materials : - Sugarcane extraction (11-15%)



$\rightarrow$  We can Sugarbeet as a raw material.

- $\rightarrow$  By products : -
- ① Bagasse (Paper Industry as well as fuel in boilers for steam gen)
  - ② Press Mud (Manure / Fertilizer)
  - ③ Molasses (Distillery)

Method / Steps  $\rightarrow$  Production of Sugar

- ① Sugarcane are shredded in crusher.
- ② Squeezed through a series of pressure mills containing grooved rollers.

(3) Continuous Settler:-

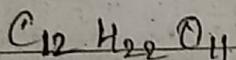
- ↳  $\text{CaHPO}_4$  + lime, → Treatment of juice  
↓ To give white colour to sugar.  
To precipitate colloids
- ↳  $\text{SO}_2$ , C bleaching agent as well as maintains PH  
 $\text{to } 7 \rightarrow 7.1$ )
- ↳  $\text{CO}_2$  ( $\text{H}_3\text{PO}_4$  C Acidifying agent)

(4) Juice is concentrated in multi-effect evaporators

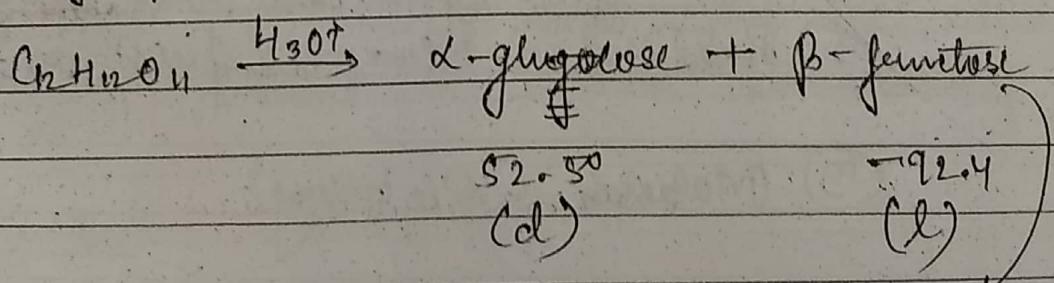
(5) Send this concn juice in vacuum pan crystallizer  
& then send to high speed basket centrifugal.  
→ Remove

- ↳ Crystal + Syrup = Massecuit
- ↳ Mother liquor (Black strap molasses)

Inversion of Sugar:- (Invert sugar)



Using polarimeter when angle =  $97^\circ$ . & diastereotropy (d)



Inverted sugar  
More sweet than  
ordinary sugar

Uses of Sugar:-

- (i) In soft drinks (ii) In Beverages (iii) In fast foods
- (iv) In ready/sweet. (v) In baking products.

### Vinegar:-

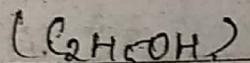
It is aqueous soln of acetic acid which have 5-20% by volume acetic acid. & its production is by fermentation of  $C_2H_5OH$  & sugar by acid bacteria.  
Used in cooking ingredients, pickling.

### Fermentation Industry:-

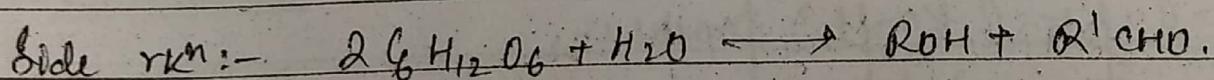
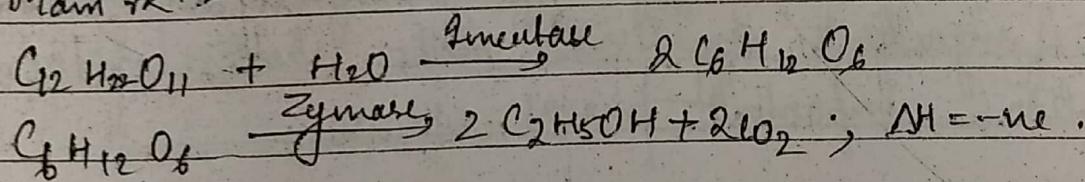
Fermentation process utilize microbiology in producing chemical compounds.

→ Medicines, Antibiotics, complex compounds (Citric Acid & lactic Acid) produced.

### Ethyl Alcohol:-



Main rxn:-



Industrial Alcohol:- 95%  $C_2H_5OH$  + 5%  $H_2O$ .

haloconty → 99.5%  $C_2H_5OH$

Uses:- → As a solvent, blending agent (forming a mixture known as Gasohol).

→ for drinking purpose.

- ↳ As a fuel & in medicines & in food additives  
in personal care products.

#### (IV) Pulp & Paper Industry:-

Pulp is a commercial cellulose derived from Bamboo, Bagasse & wood etc. by mechanical or chemical methods.

#### Methods of production:-

For pulp:-

(1) Ground Wood:- Debarked wood is mechanically shredded to form fibre suitable for production of newspaper, toilet tissue paper where strength & ease of bleaching are not important.

(2) Chemical methods:- Cellulose from wood is free from lignin & non-cellulose ingredients by ~~removal~~ with chemical reagents. The two important process are:-

(a) Sulfate (Kraft) process:-

(b) Sulfite process:-

Pulping:-

Disintegration of bulky fibre material into

smaller one.

- (1) Chipping Bin → It consists of large rotating disk with heavy knife cut to ~~2-3~~ cm in size.
- (2) Digester → Its cube like pressure cooker. Fixed to digester, we add wood chips with water with "white liquor" ( $\text{NaOH} + \text{Na}_2\text{S}$ ). In digester, white liquor act as a soap, (lignin as a) & wood chips as cloth dirt.

After digester we get fiber material free from lignin & black liquor with it.

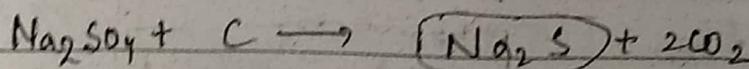
Recovery of chemicals from black liquor:-

4 ton of black liquor are produced in manufacturing of 1 ton of pulp. Recovery is done to reduce pollution & regenerate white liquor. Black liquor from pulping plant is very dilute and needs to be concentrated. For this purpose multi-effect evaporator and disk-evaporator used to change concentration from 15% to 65%.

↳ Mix Tank:

In mix tank makeup chemicals ( $\text{Na}_2\text{SO}_4 + \text{S}$ ) are added.

↳ Boiler:- Organic Carbon present in black liquor burn in boiler.



Glutaraldehyde  
is obtained from product of butyric acid  
which is obtained with cold water to  
yield green liquor which is aqueous  $\text{Na}_2\text{CO}_3$ .

White liquor  $\rightarrow$  Black liquor  $\rightarrow$  Green liquor.

Milk of lime added to green liquor for  
removal of white liquor.



### Characteristics

Sulfate  
(Chlor- process)

Sulfite process

$\rightarrow$  Process

Alkaline process.

Acidic process

$\rightarrow$  Raw materials

Fell fibres

Bamboo  
hard wood.

$\rightarrow$  Reagent used  
in digester

25%  $\text{Na}_2\text{S}$ , 60%  
 $\text{NaOH}$ ,  
 $\text{Na}_2\text{CO}_3$ ,  
15%

$\text{NaOH} - 4$
$\text{Na}_2\text{CO}_3$

(a) Magnesite process  
 $\text{Mg(OH)}_2 +$   
lime +  $\text{SO}_3$  in  
acidic medium

(b) Neutral Sulfite  
 $\text{Na}_2\text{SO}_3$ ,  $\text{Na}_2\text{CO}_3$ ,  
 $\text{NaHCO}_3$ .

(c) Acid Sulfite  
process.

$\text{NaHSO}_3$ ,  $\text{Na}_2\text{CO}_3$

$\rightarrow$  Digester condition

$T = 170 - 180^\circ\text{C}$   
 $P = 10 \text{ atm}$

$T = 120 - 150^\circ\text{C}$   
 $P = 4.6 \text{ atm}$

	Wood → 2-5 hrs	Wood → 6-10 hrs.
→ Type of pulp	Brown color ( Bleaching reqd) ( Strong pulp produced)	Dull white color

### (3) Bleaching of Pulp :-

To produce white paper, pulp is bleached. Chemicals used to bleach the pulp must be environmental friendly. Bleaching with chlorine produce di-oxine, so now a days Pulp bleached with  $H_2O_2$ , as well as  $O_3$  &  $O_2$ .

### (4) Production of paper :-

Pulp is mechanically disintegrated into fibre to make paper uniform. So for this purpose we will use Beater & this process is called Beating process. 99.5%  $H_2O$  fibres, shiny even on a belt &  $H_2O$  drained out by gravity.

### (5) Pressing :-

- ↳ Water content reduced to 60-65%. For this purpose pressure rolls & suction rolls are used.
- ↳ Water content reduced to 5-6%, and for this purpose, steam heated metal rolls used.

### (6) Finishing :-

For producing smooth paper, binding rolls are used  
 "Foudeineier Machine" → Makes the paper.

By products of pulp & paper Industry:-

- (1) Glue
- (2) Turpentine (which is a strong smelling colorless liquid used in thin paint).
- (3) Rosin → A solid/liquid synthetic organic polymer used in plastics, adhesives & in varnish.
- (4) Oil fraction

#### L.V) Petroleum Industry :-

- ↳ Petroleum → Oil from rock. These rocks are source rock or sedimentary rock.
- ↳ Petroleum is the foundation of the Industrial civilization, also known as Black Gold.
- ↳ It comes out of ground and it's worth a great deal of money.
- ↳ Fossil fuel → Fossil fuel is a fuel formed by natural process such as anaerobic decomposition of buried dead organism (means remains of plant & dead animals) containing energy.

↳ Petroleum Naphtha Oil mainly consist a mixture of HC's with small amounts of other organic compounds containing S, N, & O. The naphtha oil also contains small amount of metals such as Cu, Fe, Vanadium, Ni, Arsenic etc.

↳ Elemental composition of Naphtha Oil :-

Elements	Amount (wt%)
C	83 - 87%
H	10 - 14%
N	0.1 - 2%
O	0.1 - 0.5%
S	0.5 - 6%
Metals	< 0.1%

↳ Hydrocarbons:- They are compounds composed of hydrogen & carbon.

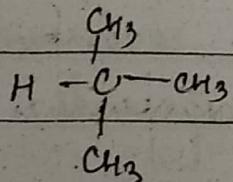
(a) Open chain / aliphatic HC's:-

Alkanes ( $C_nH_{2n+2}$ )  $\rightarrow$  Open chain (n-paraffins)

$\rightarrow$  Branched chain (isomers of paraffin)

Examples:-  $\hookrightarrow$  n-paraffins  $\rightarrow$   $C_2H_6$ ,  $C_3H_8$ ,  $C_4H_{10}$ ,  $n$ -butane,

$\hookrightarrow$  Iso-paraffins  $\rightarrow$  Iso-butane



N-Paraffins → Constitute a large fraction of most crude oil than any other. These compounds have poor anti-knocking properties.

Iso-Paraffins → These branch chain materials perform better in IC Engine than n-Paraffins and hence considered more desirable.

b) Alkenes := (Olefins) - (CnHn)

Olefins is generally absent in crude oil & these compounds are produced in cracking operation (FCC (Fluid Catalytic cracking)).

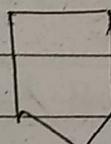
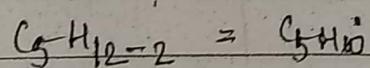
Ring Compounds:-

↳ Cyclo-paraffin (Naphthenic Compounds) →

→ These are saturated ring hydrocarbons.

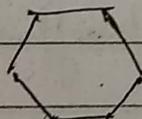
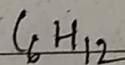
→  $C_n H_{2n+2-2N}$  where  $N = \text{no. of rings}$ .

$$N=1$$



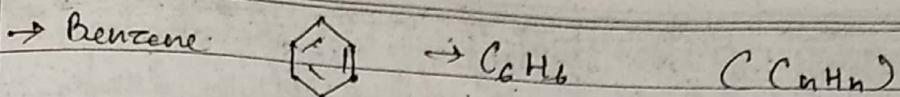
→ Cyclopentane

$$N=1$$

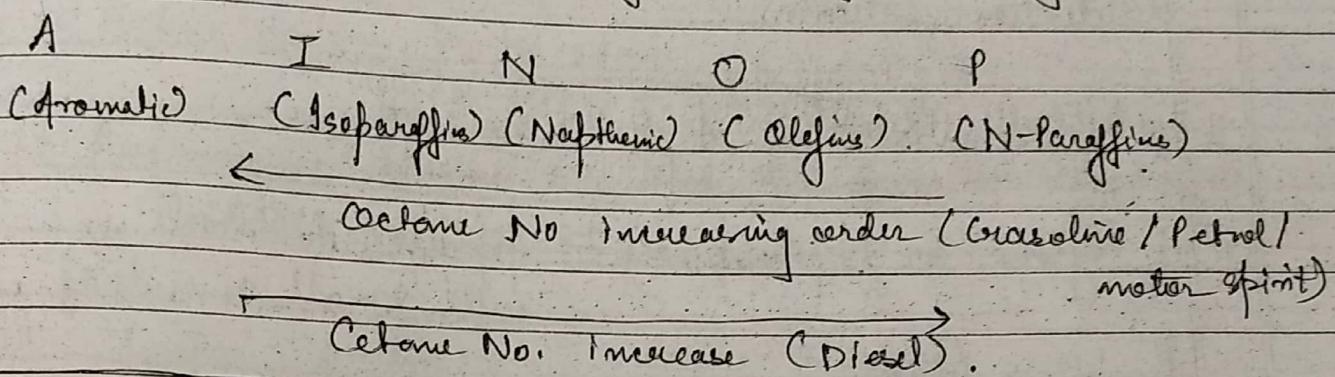


→ These compounds are 2nd most abundant series of compounds in most crude.

↳ Aromatic Compounds:- (of nenes / Benzenoid Series)



→ Aromatic compound found in crude oil in very small amount.  
These are very desirable in gasoline, since they have high anti-knock values, good storage stability.



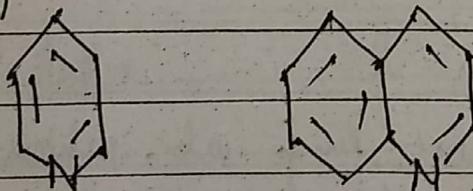
### Non-hydrocarbon Compounds:-

#### (i) S - Compounds :-

CH<sub>3</sub>SH. (Methyl mercaptan or methane thiol)  
C<sub>2</sub>H<sub>5</sub>SH. (Ethane thiol).

#### (ii) N - compounds :-

Pyridine, Quinoline.



#### (iii) Metals :- Vn, Fe, As, Ni etc. < 0.1%.

### Classification of Crude Oil :-

#### (i) Paraffinic based :-

clude oil which on distillation yield residue containing paraffin wax are called paraffinic crude.

(ii) Intermediate base:- Paraffinic wax & asphaltic materials in bottom of distillation column.

(iii) Asphaltic Base :- Asphaltic materials.

(iv) Hybrid or Naphthenic base  $\rightarrow$  Asphaltic materials with small amount of paraffinic wax.

$\hookrightarrow$  Classification of Laboratory test:-

$\rightarrow$  Volatility :- (a) Distillation Columns

(b) By measuring Vapor pressure measured by Reid Apparatus

(c) Flash & fire point.

# Flash point is lowest temp at which test flame comes vapor.

# Fire point is lowest temp at which oil ignites continuously to burn for 5 secs.

$\rightarrow$  Flash & fire point:- (a) Abel Apparatus ( $19-49^{\circ}\text{C}$ ) Closed Cup Type

(b) Penky Marten Apparatus ( $\text{Above } 49^{\circ}\text{C}$ ) Open Cup Type

(c) Cleveland Apparatus ( $< 79^{\circ}\text{C}$ ) Open Cup type

→ Combustion :- (i) Ignition quality (Octane number)

↪ Octane number → for a mixture of iso-octane & n-heptane, Octane number tells that how much % age of (Volume %) "iso-octane" is in mixture. For Iso-octane, Octane No. → 100 & for n-heptane, Octane no. → 0.

↪ Octane no. =  $\gamma_i$  iso-octane

$\gamma_i$  iso-octane +  $\gamma_n$  n-heptane.

↪ Performance Number → Used in Aviation Turbine fuel.

$$\text{Octane No.} = 100 + \left( \frac{\text{Performance No.} - 100}{3} \right)$$

(ii) Ignition quality:- (Cetane Number)

↪ "Cetane number" is a mixture of <sup>12</sup> Triacontane and.

$C_{16}H_{34}$  Cetane

(low ignition delay)

2, 2, 4, 4, 6, 8, 8 - heptamethyl nonane (high ignition delay).

Cetane No. % = % of n-cetane + 0.15% of heptamethyl nonane

↪ Diesel Index & Ailine point.

→ Ailine is a poor solvent for Aromatic HCs & excellent one for aromatics.

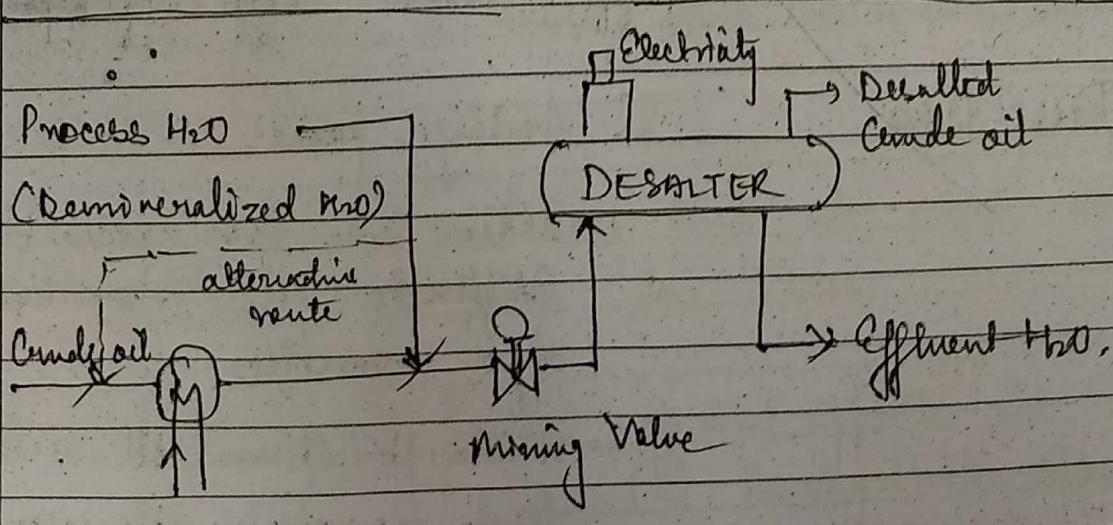
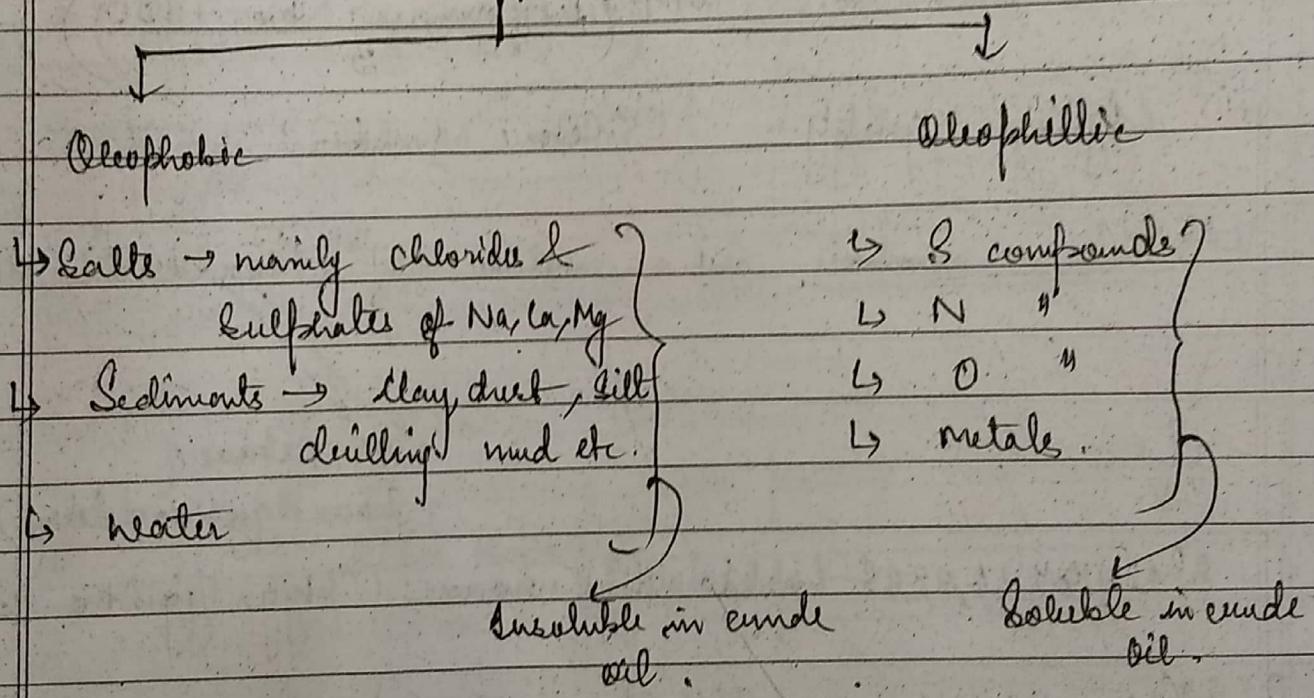
→ Ailine pt. of an oil is lowest temp at which oil is completely miscible with an equal volume of ailine.

Index & very good ignition → High ailine pt. indicate fuel is highly paraffinic & hence has high Diesel quality.

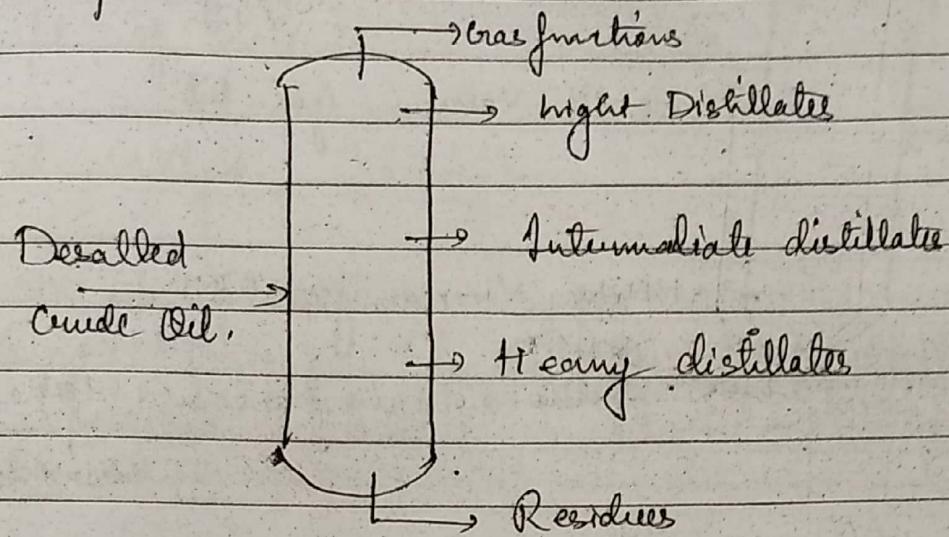
### (iii) Burning Quality :-

Smoke point → It is the maximum flame height in mm at which fuel will burn without smoking when determined in a smoke point apparatus under specified conditions. (Kerosene).

### # Electrical desalting of Crude Oil :-



## Atmospheric Distillation Unit :-

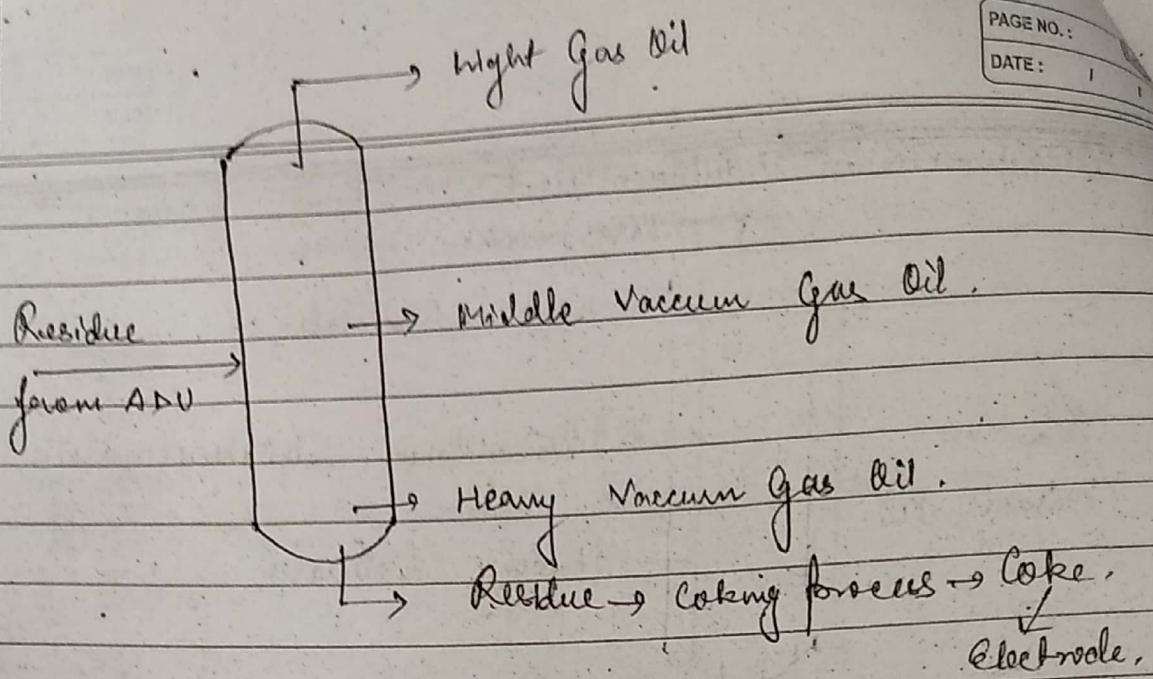


- ⇒ Gas fractions →  $C_1 - C_4$  compounds ( $CH_4$ ,  $CH_3Cl$ ), propane, butane ( $CH_3CH_2CH_2Cl$ ).
- ⇒ light distillates → Naphtha
  - Light Naphtha ( $C_5$ ,  $T < 90^\circ C$ )
  - Heavy Naphtha ( $C_5$ ,  $T > 150^\circ C$ )
  - Motor spirit (gasoline), light Gas Oil,
- ⇒ Intermediate Distillates → Kerosene, ATF, Aviation turbine fuel
  - Heavy fuel oil.
  - Diesel Oil, → Middle gas Oil.
- ⇒ Heavy Distillates → Heavy Gas Oil, Furnace Oil, lubricating Oils.
- ⇒ Residues → wax, Asphalt, Petroleum Coke, Grease
- ⇒ Byproducts → Detergents,  $NH_3$

# ~~Diagram~~

Vacuum Distillation Unit:-





### Thermal Conversion Process

Process in which HC's are decomposed at elevated temp to form material of low MW are called thermal conversion process.

Thermal decomposition of long chain oil molecule into shorter chain proceeds through Free Radical Mechanism.

### Catalytic Cracking :-

Catalytic conversion process may be classified as:-

(i) which change Carbon no. :-

(ii) Fluid CC :-

(iii) catalytic hydrocracking :-

(iv) Catalytic polymerisation :-

↳ which change C/H ratio :-

→ catalytic hydrogenation / dehydrogenation.



Neither change carbon no. nor C/H ratio only change shape of molecule  $\rightarrow$  Catalytic Isomerization.

### Fundamental Catalytic Cracking:

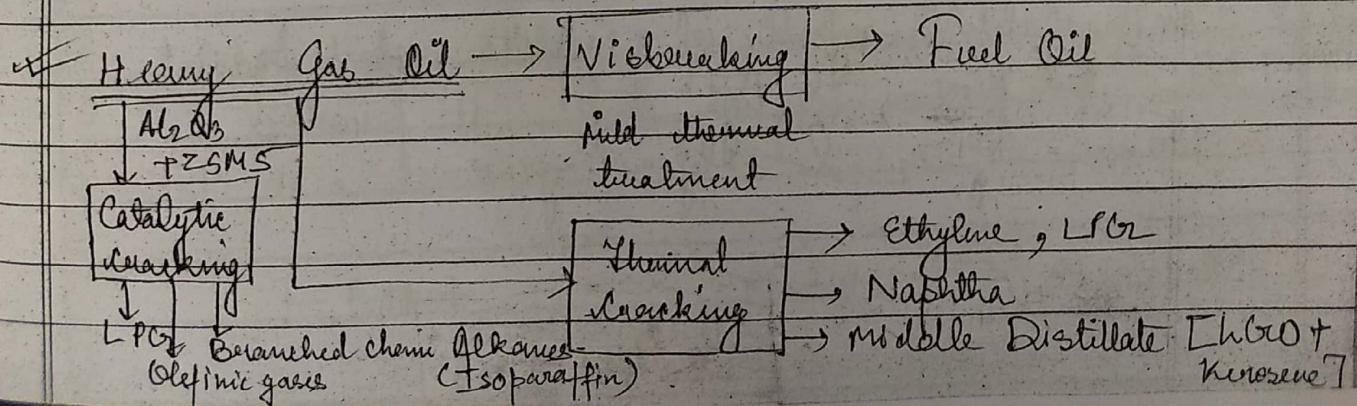
It is widely used to convert the high boiling, high MW HC's, fraction of petroleum crude oil into more valuable gasoline, olefinic gases & other products.

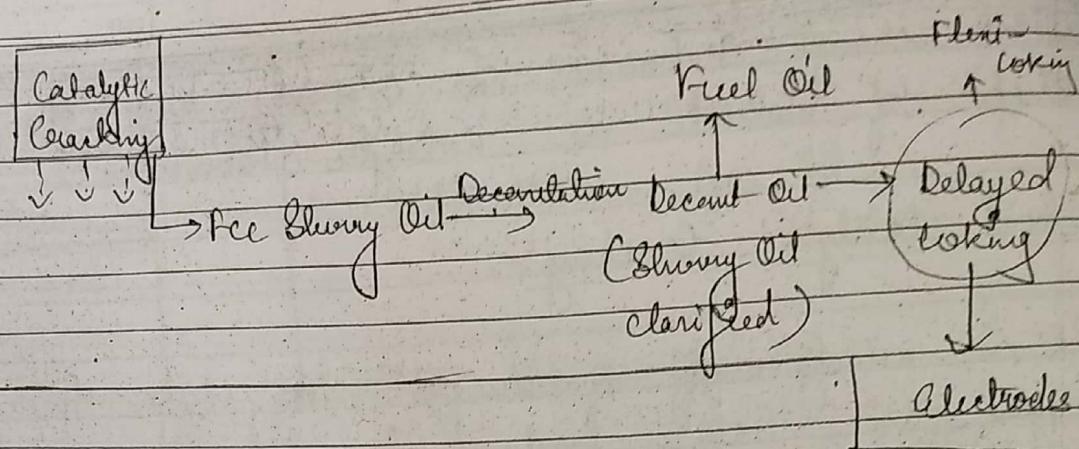
At Cracking of petroleum HC's was originally done by thermal cracking which has been completely replaced by catalytic cracking because it produce more gasoline with a high octane no. It also produce by product gases that have been more carbon - carbon double bonds [olefins]. and hence more economic value than those produced by thermal cracking.

Catalyst  $\rightarrow$  Commercial Catalyst  $\text{Al}_2\text{O}_3$  (banਸite) with zeolite XSM-5.

In FCC reactor reaction is endothermic & in regeneration exch. is exothermic.

FCC also called Energy Balance Unit.





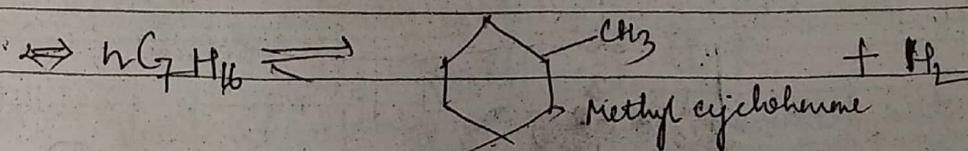
### → Hydrocracking :-

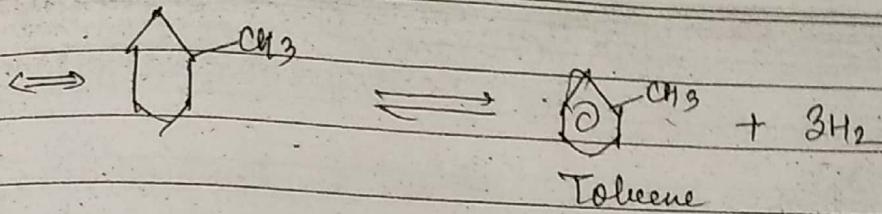
Hydrocracking of heavy residue is a high temp and high pressure process. In this process,  $H_2$  gets consumed. Hydrocracking is a most versatile petroleum refining process. Any fraction from Naphtha to Asphalt can be processed.

This process produce desired product with a molecular weight lower than feedstock. At some time, hydrocracking takes place; S, N, O are almost removed.

### → Catalytic Reforming Process:-

- ↳ In petroleum refining, catalytic Reforming used to convert paraffins & naphthenes to aromatics.
- ↳ In Catalytic reforming of Naphtha which have low pressure & high temp, it produce stream of  $H_2$  & olefinic gases.





### Hydrotreating Process:-

This includes desulfurization, denitrogenation, deoxygenation & Olefin Saturation.

↓ converts to H<sub>2</sub>S      ↓ converts to NH<sub>3</sub>      ↓ converts to H<sub>2</sub>O

n-paraffin

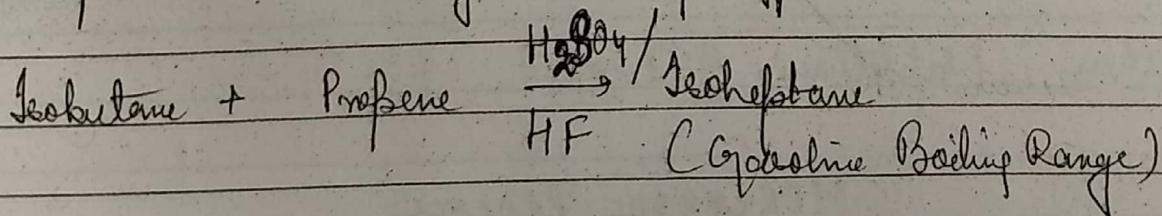
### Catalytic Polymerisation :-

The gases obtained in cracking are rich in olefins.

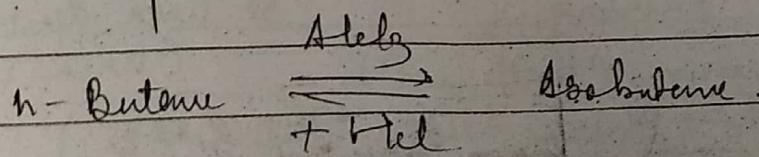
These gases goes under polymerisation in presence of catalyst which is "H<sub>3</sub>PO<sub>4</sub>", is used to make product of gasoline boiling range.

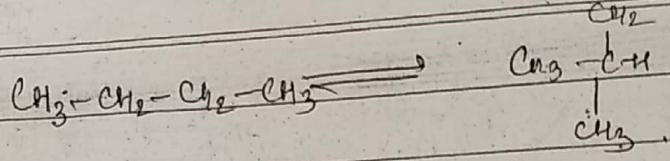
### Catalytic Alkylation :- R<sub>n</sub> in which an alkyl group added to a compound.

Petroleum refining on of an olefin with an isoparaffin to produce a longer iso-paraffin.



### Catalytic Isomerisation :- It converts n-paraffin to iso-paraffin in presence of AlCl<sub>3</sub> with fine Hg as a promoter.

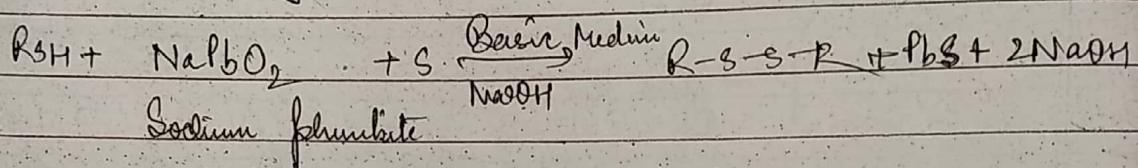




## → Sweetening process:-

Removal of S & its compounds like H<sub>2</sub>S, mercaptans etc. from petroleum products is called Sweetening.

### (1) Dr. Sweetening Process →



### (2) Catalytic desulfurization :-

Catalyst used → Barium.

### (3) Solvent Process :- → Mostly used process.

→ Extraction process.

→ Methanol & Naphthalic acid are used as solvent when Methanol used as solvent



### UNISOL PROCESS

when Naphthalic acid used



### MERCAPSOL PROCESS

## → Dewaxing process :-

(1) Chilling & heating.

(2) Solvent dewaxing (Mostly used)

(Solvent used → Propane, Methyl Ethyl Ketone.)

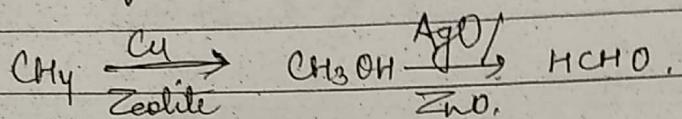
3) Urea dewaxing  
(Urea used)

- Deasphalting process - Can be done by distillation or Solvent extraction. So solvent used in solvent extraction process is "propane".
- Dearomatisation process - Mainly done for kerosene beneficiation. Solvent used → Liquid  $\text{SO}_2$ .

### Part III :- PETROCHEMICAL INDUSTRIES.

(I) Chemicals from C<sub>1</sub> Compounds →

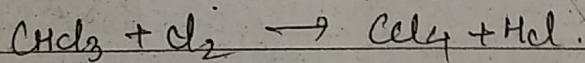
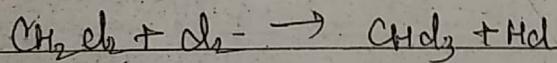
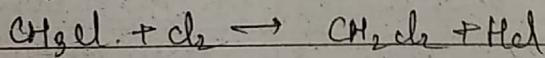
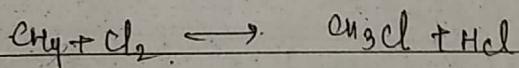
(a) Formaldehyde → Produced by Methanol where  
Methanol produced by Catalytic  
conversion of Methane.



Uses of formaldehyde:-

- ↳ Making tree formaldehyde resins
- ↳ Making phenol " " " (Bakelite)
- ↳ " [formalin + soln of 35-40% H<sub>2</sub>O in formaldehyde or methanol].

(b) Chloromethane → Addition of chlorine to CH<sub>4</sub> in absence of O<sub>2</sub> (anaerobic process).



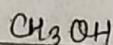
Uses:-

- ↳ As a refrigerant.
- ↳ Making a silicon polymer.
- ↳ Making tetramethyl lead.

Short Notes :-

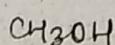
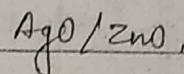
ProductRaw materialsStepsCatalyst / medium

Formaldehyde

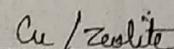


Single

(Catalytic combustion)



Single (Catalytic form)



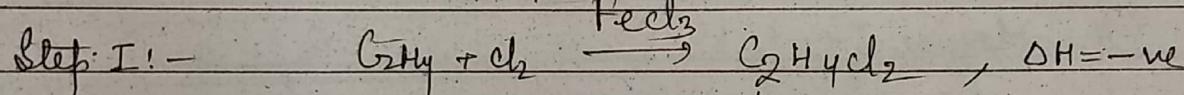
Tetrahalomethane



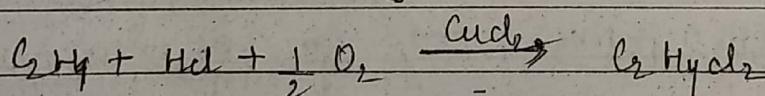
4 steps

Absence of O<sub>2</sub>Chemicals from C<sub>2</sub> Compounds:-

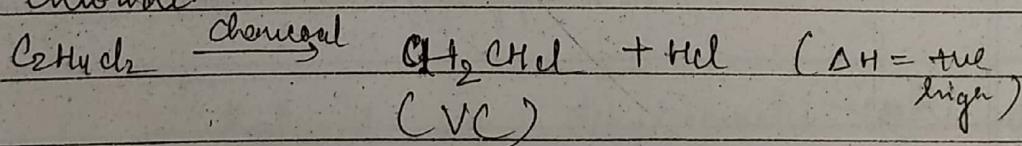
(a) Vinyl chloride → can be manufactured by Ethylene by 2 steps process.



→  $\text{C}_2\text{H}_4\text{Cl}_2$  can be produced by oxychlorination of ~~Alkene~~ Ethylene.



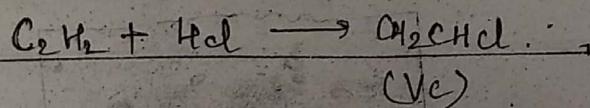
Step II:- Undergoes thermal cracking to form Vinyl chloride.



Uses:-

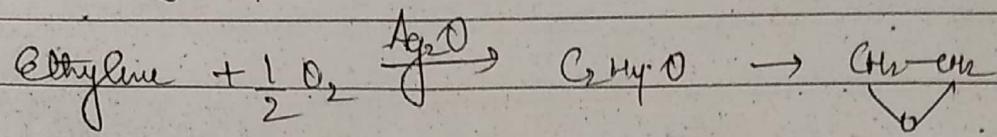
- ↳ In making PVC
- ↳ chemical intermediates forming.

→ Acetylene - HCl Rxn :-



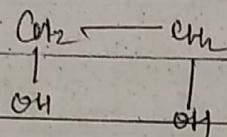
(b) Ethylene Oxide:-

Produced by partial oxidation of Ethylene.



Uses:-

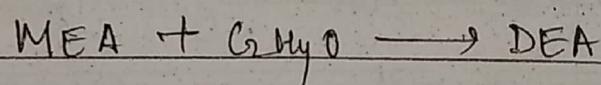
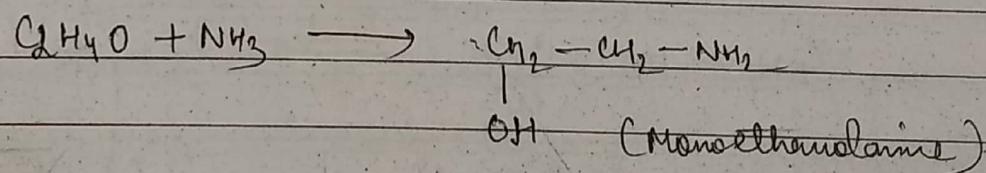
↳ Makes Ethylene Glycol. (Highly toxic)



↳ Makes polyester, detergents, pharmaceutical industry.

(c) Ethanolamine:-

Produced by Aminofication of Ethylene oxide.



Uses:-

↳ In pH control

↳ In producing detergent, emulsifier resins.

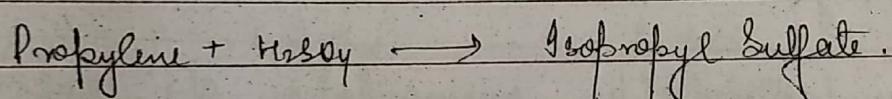
Short Notes:-

Product	Raw	Step	Catalyst
Vinyl chloride	$\text{CH}_4$	(i) Chlorination (ii) Thermal cracking	Feels Charcoal
Ethyne Oxide	$\text{C}_2\text{H}_2$	Partial and <sup>with</sup> air	$\text{Ag}_2\text{O}$
Ethanolamine	$\text{C}_2\text{H}_5\text{OH}$	Ammonification	—

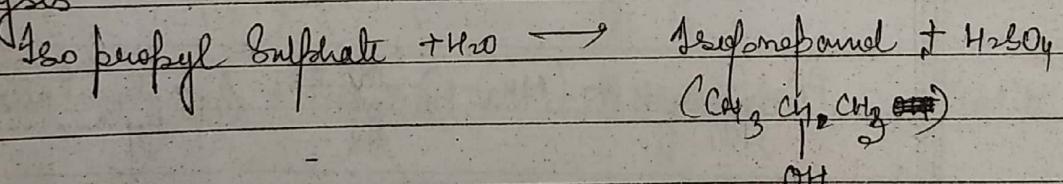
### III) Chemicals from $\text{C}_3$ compounds:-

(a) Isopropanol:- Produced from propylene by 2 step process.

① Sulfation of propylene →



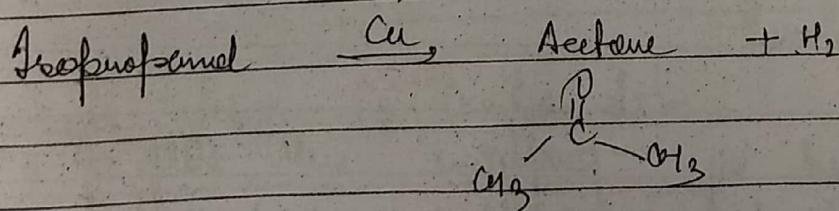
② Hydrolysis →



Uses:-

- ↳ In electronic devices
- ↳ Solvent for non-polar compounds.

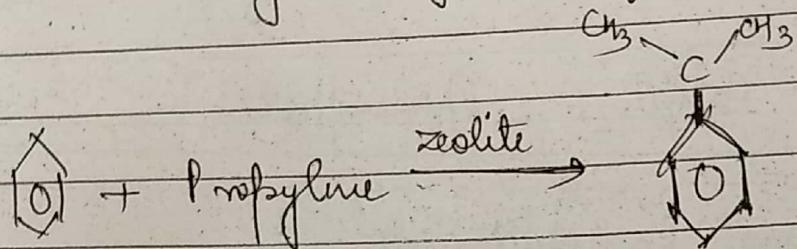
(b) Acetone:- Produced by dehydrogenation of Isopropanol



Used for thin polyester & used as solvent for bleaching.

(c) Cumene :- (1-Alkylated Benzene, Isopropyl Benzene,  
1-methyl ethyl benzene)

↳ Produced by alkylation of benzene with propylene

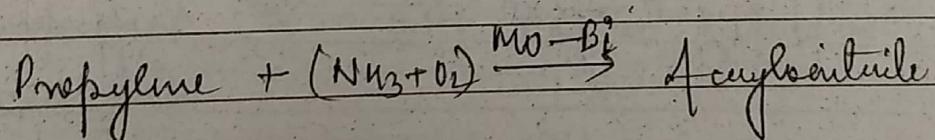
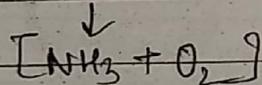


↳ Catalytic alkylation  $\text{K^n}$

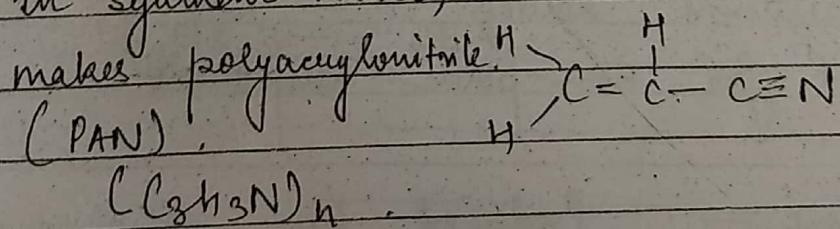
Uses :- Mostly in production of Phenol

(d) Acrylonitrile :-

Manufactured by ammoniation of propylene alone.



Uses :- In synthetic rubber,  $\text{C}_3\text{H}_3\text{N}$ .



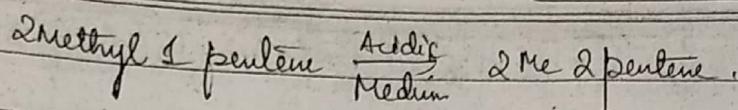
(e) Isobutene :-

↳ Produced by propylene with help of 3 steps :-

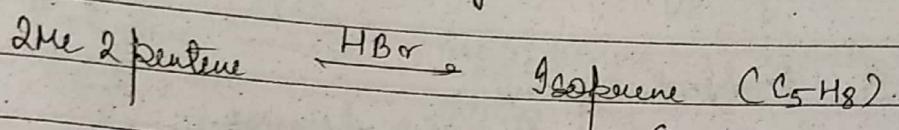
(i) Dimerisation  $\Rightarrow$  2 Propylene  $\rightarrow$  2 Methyl 1-pentene  
 $"(\text{C}_3\text{H}_7)_3\text{Al}"$

Tripropyl Aluminium

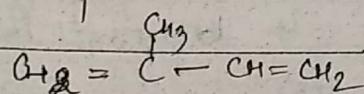
(iii) Isomerisation :-



(iii) Pyrolysis :- (P low, T high, Anerobic)



Uses:-  
→ Making Synthetic  
Rubber



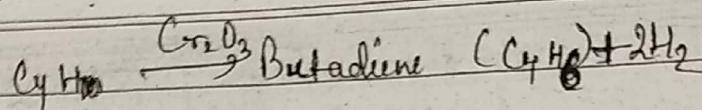
→ In Adhesives.

Short Notes:-

Compounds	Raw	Steps	Media / Catalyst
Isopropanol	Propylene	Sulfation, Hydrolysis	
Acetone	Isopropanol	Dehydrogenation	Cu
Cumene	$\text{C}_6\text{H}_6 + \text{Propylene}$	Akylation	Zeolite
Acrylonitrile	Propylene	Ammoniation	Mg-Bi
Isoprene	Propylene	Dimerization Isomerization Pyrolysis	$(\text{C}_3\text{H}_7)_3\text{Al}$ Acidic HBr

(IV) Chemicals from C<sub>4</sub> Compounds:-

④ Butadiene :- Can be produced by butane, by dehydrogenation or  $\text{K}^n$ .



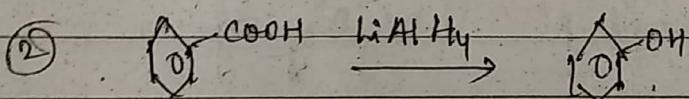
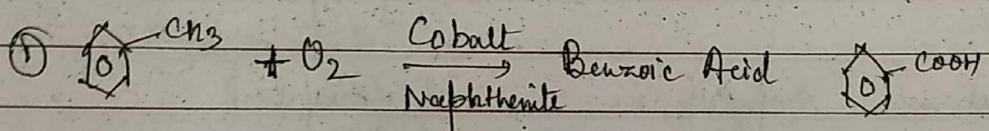
Uses:- Making synthetic rubber.

(b) Phenol:- Produced by :-

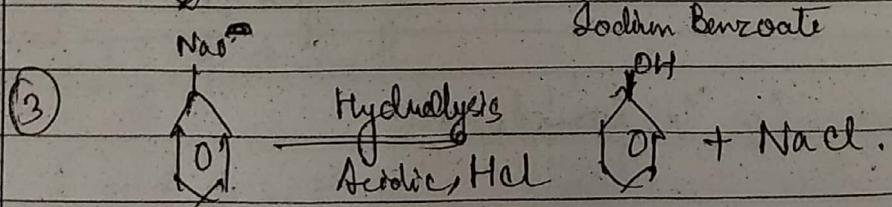
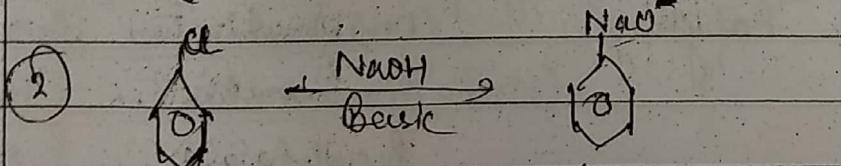
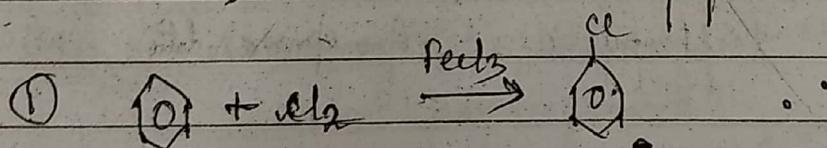
↳ Cumene - two step process.

- ① Cumene + Partial oxidn with air  $\xrightarrow{\text{Basic medium}}$  Cumene hydroperoxide
- ② Cumene hydroperoxide  $\xrightarrow[\text{(acidic medium)}]{\text{hydrolysis}}$  Phenol + Acetone.

↳ From Toluene - two step process.

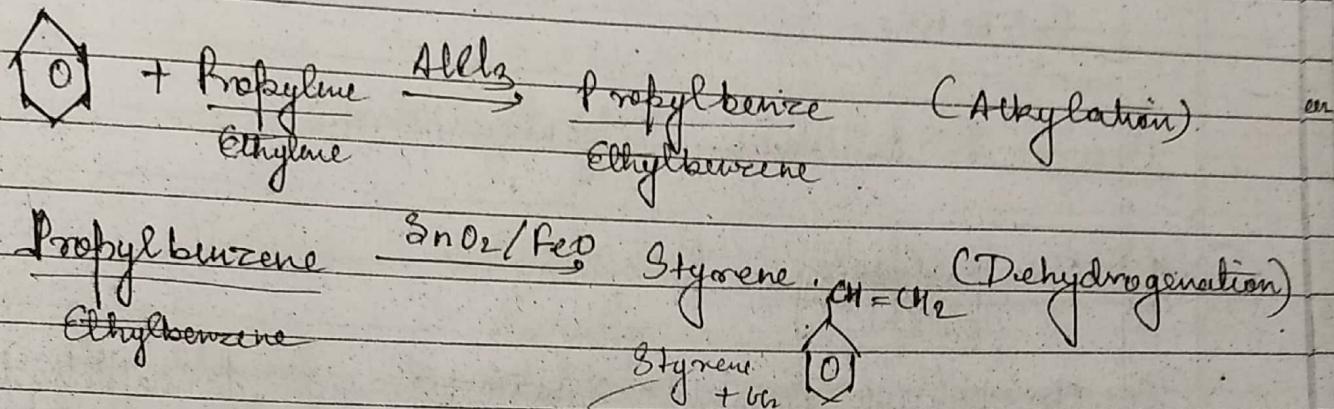


↳ Benzene  $\rightarrow$  3 step process.



Uses:- Cosmetics, phenol formaldehyde resin.

c) Styrene :- Can be produced by benzene by 2 step process.

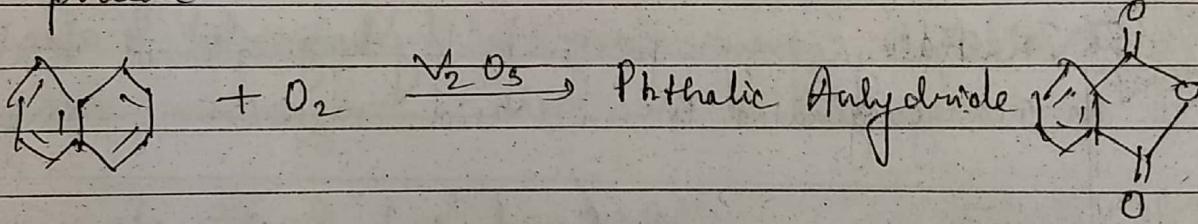


Uses:- Making Rubber, Insulation, pipes.

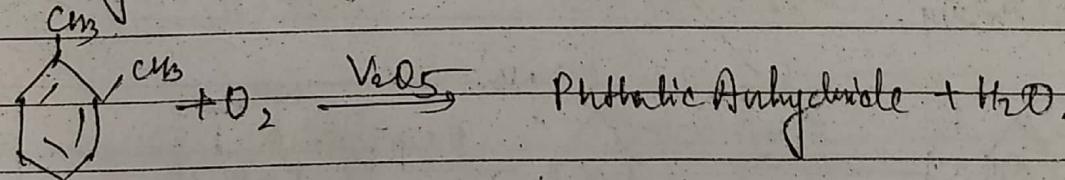
d) Phthalic Anhydride:-

Can be produced from Naphthalene / Ortho-xylylene.

Naphthalene

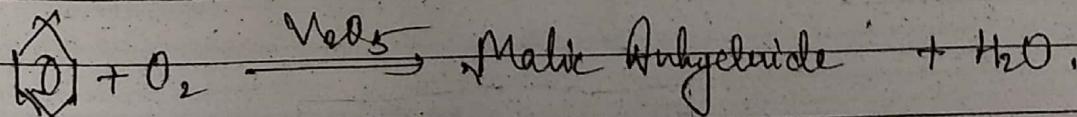


Ortho-xylylene



Uses:-

e) Malic Anhydride:- Obtained from anhydride of Benzene;

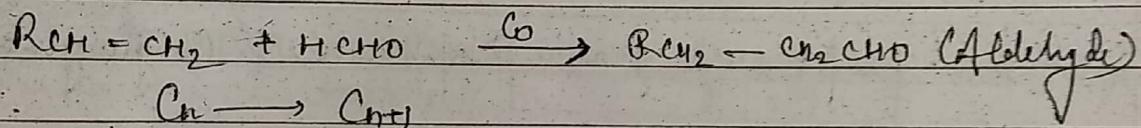


Now most of maleic anhydride is not produced by Benzene anhyd but by vapor phase oxidn of n-Butene.

Uses:- In addition, polyester resins.

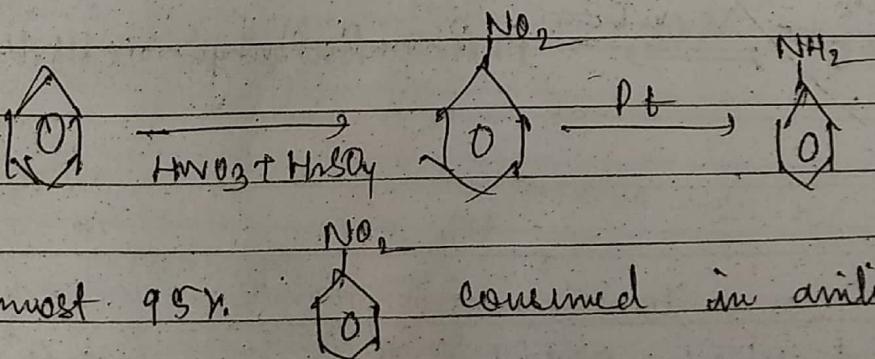
(1) One-processing :-

One-process involves substitution of formaldehyde across double bond, hence name hydroformylation. Reactant are an olefin & synthesis gas. Primary product is an aldehyde with 1 additional C atom.



~~D~~ Aldehyde group may be hydrogenated to alcohol or oxygenated to an acid.

(g) Nitrobenzene :- Produced by heating benzene with nitrating mixture of  $\text{HNO}_3$  &  $\text{H}_2\text{SO}_4$ .



Almost 95% concerned in aniline production

Short Notes:-

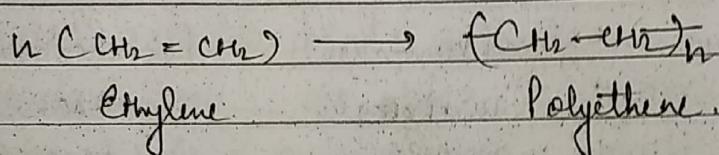
Compounds	Raw	Process Name	Catalyst
→ Butadiene	Butane	→ Dehydrogenation	$\text{Cr}_2\text{O}_3$
→ Phenol	Cumene	→ Partial Oxd <sup>n</sup> → Hydrolysis	Baek medium Acidic "
Toluene		→ Partial Oxd <sup>n</sup> → Reduction	Cobalt Naphthenate $\text{LiAlH}_4$
Benzene		→ Chlorination → Causticization. → Hydrolysis	$\text{FeCl}_3$ $\text{NaOH}(\text{BaOH})$ $\text{HCl}$ (Acidic)
→ Styrene	Benzene	→ Alkylation → Dehydrogenation	$\text{AlEt}_3$ $\text{SnO}_2/\text{FeO}$
→ Phthalic Anhydride	Naphthalene / Ortho-quinone	Partial Oxidation	$\text{V}_2\text{O}_5$
→ Maleic Anhydride	Benzene	Oxidation	$\text{MnO}_2$
	n-Butene	Vap. phase Oxd <sup>n</sup> .	
→ Oxo processing (Aldehyde)	Alkene	Oxo-process	Co
→ Aniline	Nitrobenzene	—	Pt
→ Nitrobenzene	Benzene	Nitration	$\text{HNO}_3 - \text{H}_2\text{SO}_4$

(IV) Chemical compounds few in Aromatics:-

#### Part IV :- Polymerisation Industry

- ↳ Polymers are large chain molecules having higher mw. They are made of a single units repeatedly several times within a chain structure.
  - ↳ Polymers can be produced by 2 process →

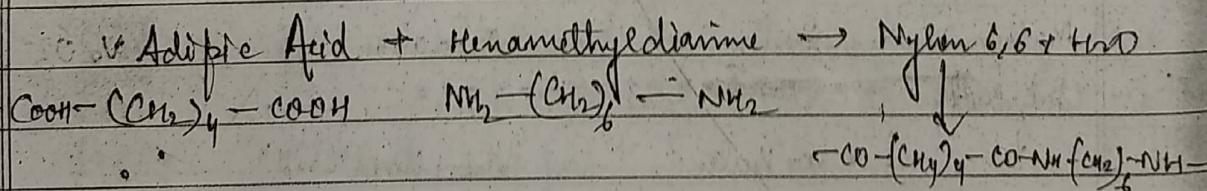
(i) addition Kinetics :-



(ii) Condensation kinetics :-

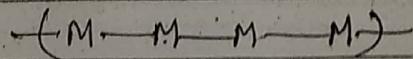
It takes place for monomer having functional group and there is elimination of small molecules.

Nylon - 6, 6. ?

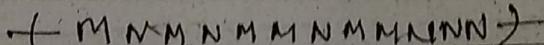


- ## Types of Polymers:

① Homopolymer:- A single monomer mit.



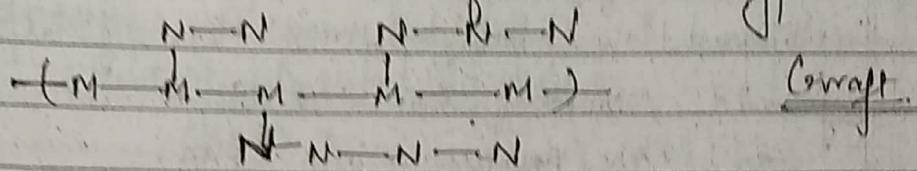
② Copolymer :- More than one monomer used  
 $\rightarrow M_1 M_2 N M_3 M_4 N M_5 M_6 N N$



(3) Block Polymer  $\rightarrow$  Polymer formed by block of monomers,  

$$(MMNN) (MMMM) (NNN) (MMMMMM)$$

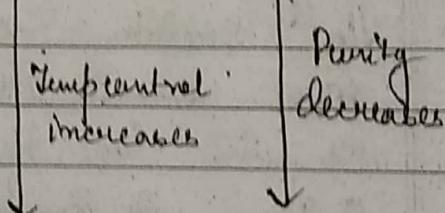
(4) Graft Polymer  $\rightarrow$  Main chain is of one type monomer &  
 Side chain of another type.



5) Types of polymerisation:

- (a) Based on temperature control.
- (b) " " purity of polymer
- (c) " " end use of polymer.

(1) Mass/Bulk polymerisation:  
 (2) Solution polymerisation:  
 (3) Suspension "  
 (4) Emulsion "



(1) Mass/Bulk polymerisation  $\rightarrow$  This mode of polymerisation is used to obtain the purest form of polymer.

This method involves only the monomer molecule, initiator & chain transfer agent (it is added when different molecular weight compounds are needed).

In bulk polymerisation large amount of heat released which can't be controlled by coolant jacket.

Ex:- Polystyrene, Thermoplastics.

(2) Solution polymerisation :- In inert solvent is added to reacting component in vessel.

The solvent enhance heat capacity therefore better heat transfer possible.

Compared to bulk polymerisation, final product formed, contains some solvent traces.

Ex:- PAN, Polyacrylic acid (PAA).

(3) Suspension & Emulsion polymerisation :-

- ↳ In order to control large amount of heat release in bulk polymerisation, suspension & emulsion polymerisation developed.
- ↳ The reaction mass (monomer / solvent) is dispersed as a minute droplets of size ( $0.1 \rightarrow 1\text{ mm}$ ) in diameter in suspension polymerisation or less than  $0.1\text{ mm}$  in emulsion polymerisation.
- ↳ Each of these droplets act as a tiny bulk reactor, HT occurs from droplet to solvent & better heat control is there because of reduced size.
- ↳ Agitator are used in suspension in order to maintain specific droplet size in dispersion while emulsifying agents used in emulsion polymerisation.  
Ex:- PVC, Styrene Resin etc  $\rightarrow S_p^n$ .

SBR (Styrene Butadiene Rubber), Chloroprene, Nitrile Rubber, Acrylate Rubber etc  $\rightarrow E^n$ .

Types of Plastics:-

(i) Thermosetting plastics:- (Thermoplastics)

The thermoplastics are chain polymers that usually become soft when heated and can be mold again & again under pressure.

Examples:

Polyethylene (Polythene), Polypropylene, PVC  
Polystyrene, Polycarbonates

(ii) Thermosetting polymers plastics:- Thermosetting plastics

are network of long chain molecules that are cross-linked. Because of cross linked, they polymerise irreversibly & can't be mold under heat & pressure.

Ex:-  $\hookrightarrow$  Urea formaldehyde resin

$\hookrightarrow$  Phenol formaldehyde resin (Bakelite).

$\hookrightarrow$  Melamine formaldehyde resin

$\hookrightarrow$  Epoxy resin

(i) Polyethylene:- As of 2017, over 100 million tons of polyethylene resin are produced annually accounting for 34% of total plastic market.

High pressure process

Intermediate pressure process

low pressure process

$P \rightarrow 1000 - 2500 \text{ atm}$

$30 - 100 \text{ atm}$

$6 - 10 \text{ atm}$

Developed by Imperial chemical Industry (ICI)  
by free radical polymerisation

Developed by Phillips Petroleum Corporation  
USA.

Developed by Karl-Ziegler  
in Germany  
by Ziegler-Natta  
Polymerisation

High $H_2O_2$ , catalyst used	Intens.	Low. Zeigler catalyst used. $[TiCl_3 + Al(C_2H_5)_2Cl]$
(LDPE) low density polyethylene produced. $\rho = 0.91 - 0.92$ g/cc.	(HDPE) High density polyethylene produced. $\rho = 0.97$ g/cc	High density polyethylene produced. $\rho = 0.96$ g/cc

Uses:-  $\hookrightarrow$  In packaging  $\hookrightarrow$  In bottles  
 $\hookrightarrow$  In plastic bags.  $\hookrightarrow$  In buckets, pipes  
 $\hookrightarrow$  In few tanks for weak acid  
 $\hookrightarrow$  Insulation for high voltage electrical cables

(2) Polypropylene :- It is produced by low pressure  
 process (Carl Zeigler process).

(3) Polystyrene :- It is produced from styrene  
 by addition kinetics.

Uses:-  $\hookrightarrow$  Because of its ease of fabrication,  
 thermal stability, low cost, it finds  
 wide application in wire & cables,  
 shoe sole etc.

(4) PVC :- It contains 56.8% chlorine & balance  
 are HCs. A major portion of chlorine  
 produced in world is used in manufacturing  
 of PVC.

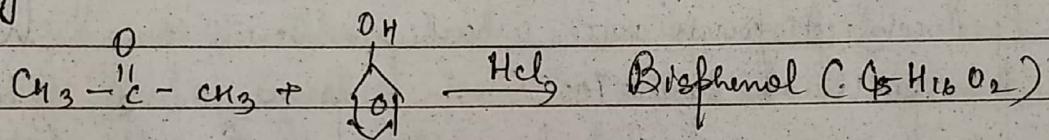
PVC produced by Vinyl chloride in presence of  
 Butyl lithium catalyst.

With addition of plasticizer rigid PVC can be converted to flexible PVC. Plasticizer used is Phthalates.

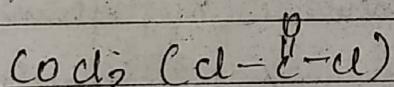
Uses:- Can be used as rigid PVC in fittings & bottles  
& flexible PVC can be used in wire & cables, footwear  
insulation etc.

Poly carbonates :- It is produced by sodium salt of Bisphenol and Phosgene in presence of organic solvent.

Bisphenol can be produced by ~~reac<sup>n</sup>~~<sup>reac<sup>n</sup> of aldehyde with a large excess of phenol in presence of acidic catalyst.</sup>



Phosgene also known as Carbonyl dichloride.



Poly carbonates also known as Engg. Plastics.

Uses:- It is a clear plastic used in shutter lenses of cameras in the area of optical clarity (light weight eye glass lenses).

Phenol Formaldehyde Resin :- It is an oldest thermoset polymer produced by condensation process of phenol & formaldehyde.

(i) NOVOLACS PFR :-  $\xrightarrow[\text{Phenol}]{\text{HCHO}} \rightleftharpoons$  Acid Catalyst.

(ii) Resolves PAF 2- $\frac{\text{HCHO}}{\text{Phenol}} > 1$ , Basic Medium.

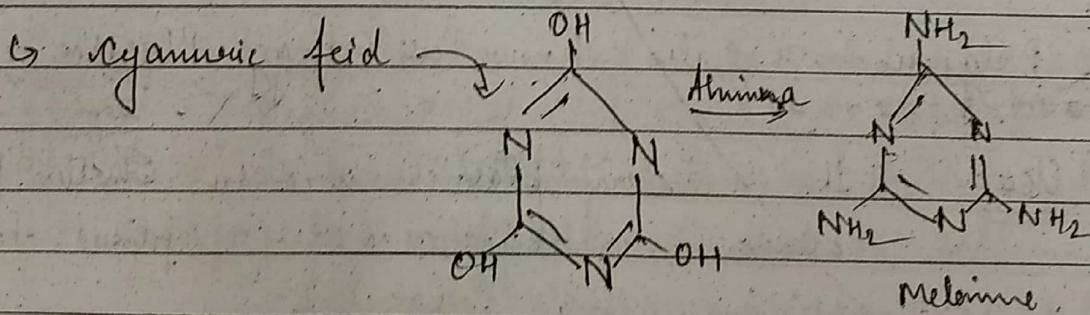
Uses:- Used as Adhesive. (main)

(2) Urea formaldehyde Resin:- It is produced by  
CUF.R condensation process  
 of urea & formaldehyde.

Uses:- Used as a Adhesive in paper & textile industry.

(3) Melamine formaldehyde Resin :-  $\hookrightarrow$  It is advanced form of UFR.  
 $\hookrightarrow$  Production of Melamine :-

Produced from urea when molten urea heated about  $360-400^{\circ}\text{C}$ . in presence of Quartz, then urea decompose into Cyanuric Acid & Ammonia. Further Cyanuric acid converted to Melamine in presence of Ammonia



Because it has better thermal & chemical resistance, mainly used in non-breakable crockery.

(4) Epoxy Resin:- Made by Reaction b/w Bisphenol & Epichlorohydrin.

Uses:- Mainly used in Paint Industry & textile industry.

## FIBRES:-

Natural fibres → Jute, Cotton, Wool.

### ① Polyamide Fibres:-

Nylon      Nylon 6,6

Nylon 6 → Produced by polymerisation of Caprolactum.  
Also known as Poly caprolactum.

Uses :- Making clothes, rope, thread, Net.

Nylon 6,6 → Uses :- (i) Gear wheels.

Hardness of Nylon 6,6 is 12% more than Nylon 6.

### ② Polyester:- (PET) Polyethylene Terephthalate.

Polyester is a category of polymers that contains ester functional group in their main chain.

#### Types:-

##### ① Dacron

Dacron is a condensation polymer of dimethyl terephthalate (DMT) & ethylene glycol (EG), where DMT produced by esterification of paraxylene & para toulue.

##### ② Mylone

It is a condensation polymer of bisphenol terephthalate (PTA) and ethylene glycol where PTA produced by endon of benzylene.

Dragon & Seagull both use caustic as a catalyst.

It can be 100% recycled & it has bright sunlight.

Uses:-

Making clothes, packaging of foods.

### (3) Acrylic fibres :- (Synthetic fibres)

Types:-

Olon

Dynal

→ Monomer is Acrylonitrile. → Monomer is Acrylonitrile  
vinyl chloride.

→ Olon is a class of → Known as modified  
acrylic fibre acrylic fibre.

Uses:- Mostly in clothing.

### (4) Cellulosic Fibres :-

Rayon → Rayon is made from cellulose which  
is derived from natural occurring material.

Rayon fibres are of 3 types:-

- (a) Viscous Rayon :- Xanthate Rayon
- (b) Acetate Rayon
- (c) Cupro - formolinium Rayon.

(a) Viscous Rayon :- Raw material → Cellulose, Caustic Soda  
&  $\text{CS}_2$ .

This process is called Xanthate process.

⑥ Acetate Rayon → Raw material is Wood pulp, acetic anhydride &  $H_2SO_4$ .

i) Cupro-NH<sub>2</sub> → Raw → Cellulose & Copper Salt  
 $Cu(NH_3)_2(OH)_2$ .

ELASTOMERS:- Natural & Synthetic polymer having elastic properties

① Styrene Butadiene Rubber (SBR):- (BUNA-S)

Styrene reacts with Butadiene  $\xrightarrow{NaOH}$ , SBR.  
Uses:- Used in tyre & tyre related products.

② Polybutadiene :-

Not directly used as product but used as a blending agent with SBR to improve its property.

③ Nitrile Rubber :- Also known as BUNA-N,  
(CNR).

Acrylonitrile + Butadiene  $\xrightarrow{NaOH}$ , Nitrile Rubber.

④ Polysoprene → It is a natural elastomer derived from Hevea Tree, It can be produced by isobutylene (synthetically).

⑤ Neoprene → Purely synthetic rubber, Also known as Polychloroprene. Made from Chloroprene with which will react with Acetylene.

### ⑥ Butyl Rubber:- (Poly Isobutylene) (PIB)

- ↳ Raw material is Isobutylene & Isoprene.
- ↳ To improve property of PIB, 2% isoprene is added in it & final product is known as Butyl Rubber

Uses- Making balloons & also used for air tight purpose.

### ⑦ Silicon Rubber:-

Made from monomer siloxanes + Si-O- functional group. They have exceptional electrical & mechanical performance under extreme temp conditions, therefore used in electrical applications like computer keyboard, remote control bracelet & also used in aerospace industry.