

28 NOV, 2022

APPLIED CHEMISTRY

UNIT-2

POLYMERS

- what are polymers
 - classifications
 - Prep., Prop., Appl.

Books

- Sunita Ratan
 - Shashi Chawla
 - Jain & Jain
 - OP Agarwal
 - VK Sharma

Poly:- Many Mon:- parts

a) joined in chain like manner.

b) These are High Molecular Weight compound (Macromolecules)

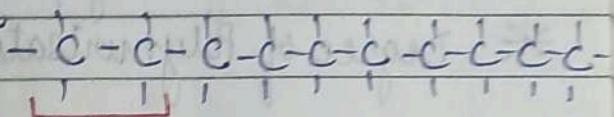
$$\text{Eg: } \begin{array}{c} 5 \text{CH}_2=\text{CH}_2 \\ \text{C}_2\text{H}_4\text{H}_2\text{H}_2\text{H}_2 \end{array}$$

Ethylen

(monomer)

$$\text{CH}_2 \dot{-} \text{CH}_2 - \text{CH}_2 \dot{-} \cdot \text{CH}_2$$

Polymerisation



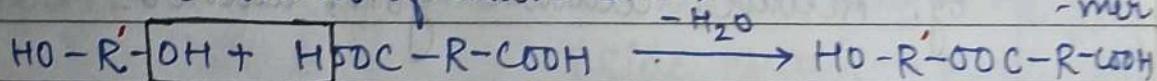
Poly ethene

Repeating Unit.

(Addition polymers)

Keyword :- Functionality

Functionality :- presence of double/triple unsaturation or chemically active functional group.



(condensation polymers) \rightarrow functional grp

Functionality of Ethene = 2

" of Alcohol in Eq = 2

Bi-functional = linear chain

Tri-functional = Branched chain

Repeating unit

If R is same: $\rightarrow C-O-R$

If R is diff :- $-R' - C$

If R is diff :- $R' - \underset{O}{\underset{\parallel}{C}} - O - R -$

CLASSIFICATIONS

1. Depending upon synthesis, we have
Condensation & Addition polymers.

四

CONDENSATION

- (a) Elemental compounds are different
 - (b) No need of initiators
 - (c) comparatively short chains (\downarrow M.W)
 - (d) Cross-linked or 3-D structure.
 - (e) Chemical funcⁿ grp shows ^{this} unsaturated Compounds

* Degree of Polymerisation :- No. of repeating Units

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ADDITION

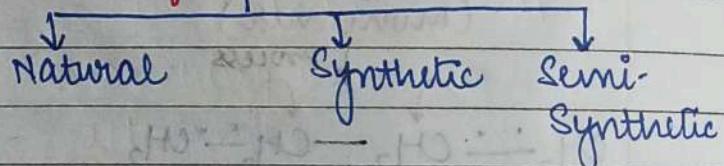
- re (c) chemical Elemental compound remains same

(b) ~~Need~~ Need initiator like heat or any chemical / radiation

(c) Long chains ($\uparrow M \cdot W$)
 $M \cdot W$ = molecular weight

(d) Linear or branched

#2. Classification on the basis of Source

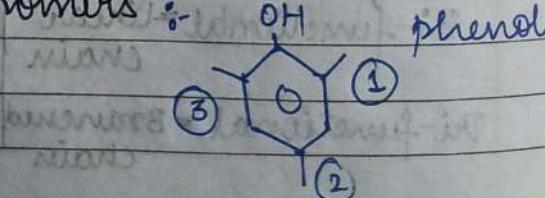


- (a) Natural polymers:- Directly from nature, Eg:- Natural Rubber, protein, cellulose, starch

(b) Semi-Synthetic :- Slight modification in natural poly.
Eg:- ^{cellulose}Acetate, cellulose rayon, leather.

(c) Synthetic (man Made) Polymers:- Artificially prepared.
Eg:- bakelite, PVC, Teflon, BUNA-S

Eg of Trifunctional monomers :- OH  phenol



EPDM:- Ethylene propylene diene monomer.

CLASSTIME/Pg. No.

Date: / /

#3. Type of Monomers

Homopolymers
(made of 1 type of monomers)
Eg:- PVC, PE,

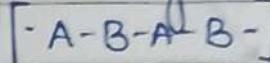


Date: - 25 Nov, 2022

co-polymers

Made of more than 1 type of monomer

Eg:- Polyester, Urea formaldehyde, phenol formaldehyde



Bakelite

Buna-S, etc

#4. Classification of copolymers on the basis of arrangement of monomers

Alternate

Block

Random

Graft

(a) Alternate :- A-B-A-B-A-B . Gives strength

(b) Block :- -A-A-B-B-B-A-A-B-B-B-

Strength:- Alt > Block > Random

(d) Graft:- -A-A-A-A-A
 B
 B
 B

(main chain \rightarrow one type
(side chain \rightarrow other type)

#5. On the basis of Degree of Polymerisation

Oligopolymers

high polymers.

According to requirement, we can modify polymers.

PS :- Polystyrene

PMMA :- Poly methyl Meth Acrylates (Contact lens)

CLASSTIME Pg. No.

(A) Oligopolymers :- low value of n , \downarrow chain length, $M_w \downarrow$, Solubility \uparrow , Strength \downarrow

(B) High polymers :- high value of n , \uparrow chain length, $\uparrow M_w$, \uparrow Strength, \downarrow solubility.

#6. Based on physical structure

Linear

For eg:- PE, PVC



Cross-linked

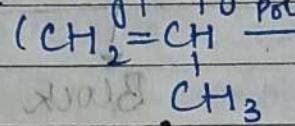
(Highly compact
& \uparrow strength)



Branched

PB diene,

Polypropylene



urea formaldehyde,
Silicon (mostly condens)
Bakelite, melamine

(affects Mech Prop at large)

Isotactic

Side branch on
same side on
chain

Syndiotactic

Branching on
alternate
side.

Atactic

No regular arra-
ngement of Side
branch

compact

Arrangement

most compact

arrangement

Strength \downarrow , loose

arrangement

Tensile strength :- cross-linked $>$ linear $>$ Branched

Polypropylene Shows all 3 types of branching

#7. Arrangement of Monomers / Polymeric chain

[Poly acrylates]

[Poly carbonates \rightarrow PET, PS]

Regular & compact
arrangement

Mech. Str. \uparrow , Refractive
transparent, Index

Amorphous (Teflon)

Irregular & loose
arrangement

Mech. St. \downarrow , Refractive
opaque, Index

Strength :-
Plastic > Fiber > Rubber

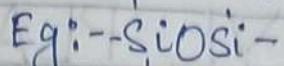
Si → linear → Rubber
Poly

Si → cross linked → Plastic

Basis of chemical structure

Organic.
(C, N, O, organic in main chain)

Inorganic
(Inorganic material in main chain, Si)



Thermal prop ↑, Mech St. ↑
chemical resistance.

#9 Basis of End Use :-

Plastic	Rubber (elastomers)	Fiber	Resins
Mech. St. ↓	Abrasion ↓ Structure weak Chemical Resist. ↓	Elongation of Plastic.	Epoxy, urea
chemical bond ↑	chemical bond ↓ Sports article, automobile, rubber tubes.	Nylon, teflon formal. fiber, terylene ↓ fibre	semi-liqu & then hard used in paints adhesive.

Eg: - Styrene butadiene

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#10 Depending on Effect of Heat / Recyclability

Polymer heated shows diff effects

- (a) Thermoplastic
can be reheated
used to make other object.
- (b) linear or branched structure
- (b) Thermosetting
if heated, it will burn
& can not be reshaped.
b/c crosslinks will break.
- (b) crosslinked structure

THERMOPLASTIC :-

PVC, Polystyrene

THERMOSETTING PLASTIC :-

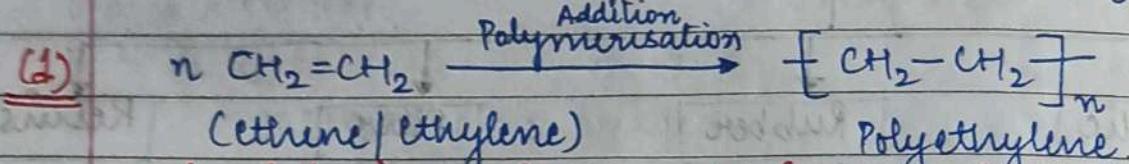
Eg:- Bakelite (phenol formaldehyde)
Melamine

VINYL PLASTICS.

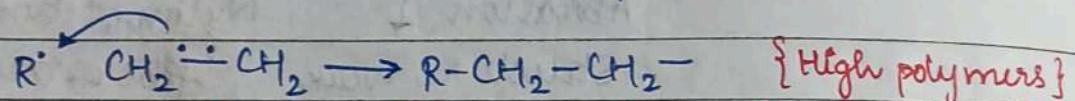
(Addition polymers)

Vinyl group :- $\text{CH}_2=\text{CH}_2$
 $\text{R}/\text{X}/\text{H}/\text{N}/\text{COOH}$

Plastics with monomers of vinyl grp are Vinyl plastics

Since it is free Radical mech, its Free Radical addⁿ polym.

Initiator :- Heat / free Radical species.

Polyethylene is linear / branched chain polymer $\xrightarrow{\text{Thermo}} \text{plastics}$

Polyethylene is of various types

- | | | | |
|-------------|-----------------------------|--------------|--|
| (a) LDPE | (b) LLDPE | (c) HDPE | (d) UHMWPE |
| (Branches) | Linear low Density polyeth. | High density | $\xrightarrow{\text{to}}$ Ultra high MW PE |
| Low Density | | | |

Properties (General)

- flexible
- Strength can be changed
- Linear / branched
- High polymers
- Addⁿ polymerisation

Properties

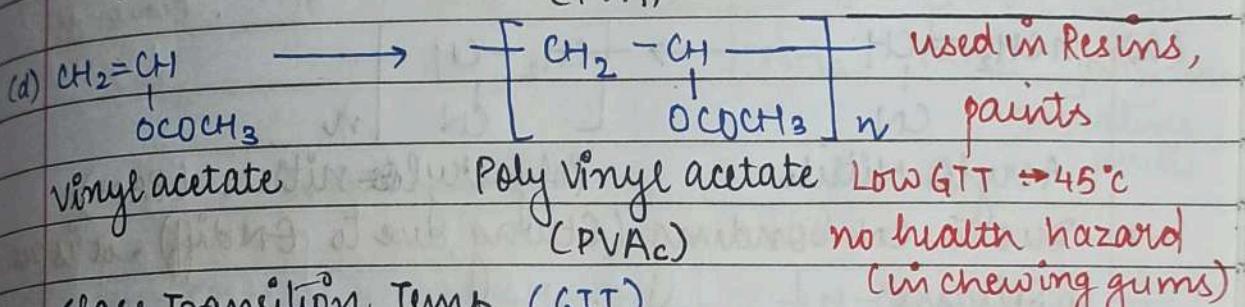
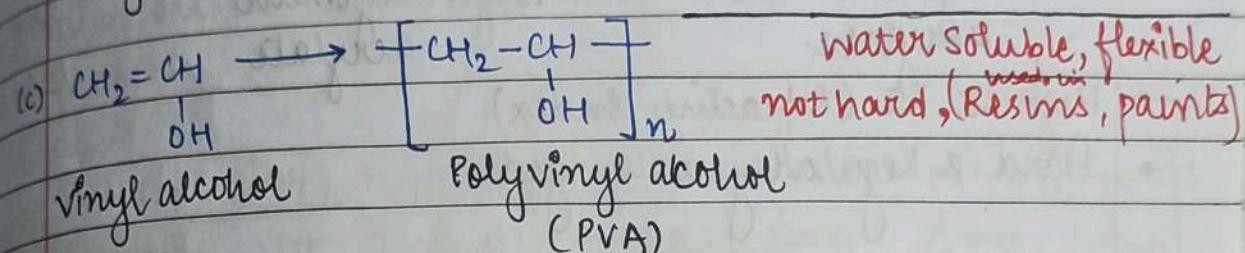
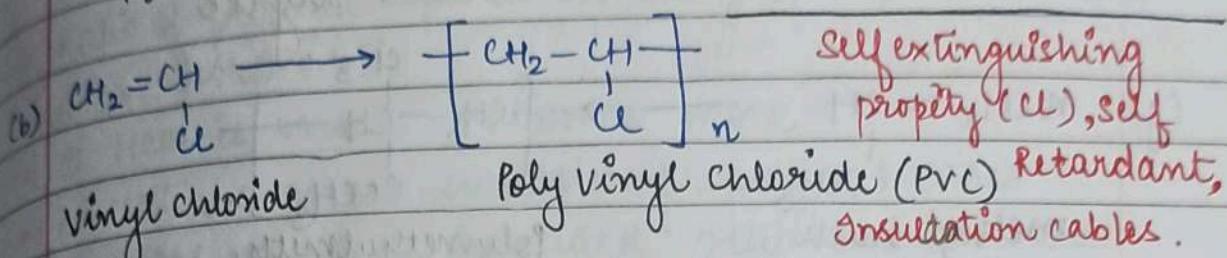
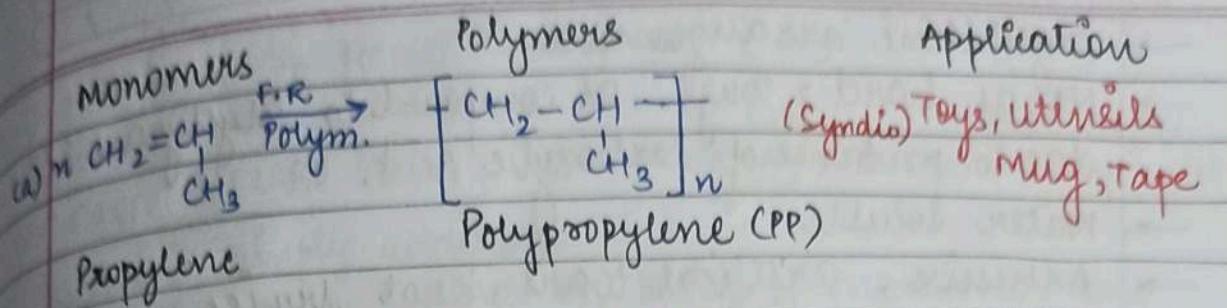
- LDPE :- High degree of long chain or short chain branches
 LLDPE :- High degree of short chain branches
 HDPE :- Linear or ~~to~~ low degree of short chain branches
 UHMWPE :- Linear long chain (1-2.5 lacks repeating units)

Catalyst

- HDPE :- Phillips catalyst / Chromium
- LLDPE :- Ziegler Natta Catalyst
- UHMWPE :- Metallocene Catalyst

Catalyst :- Metallocene catalysts

Strength :- LDPE < LLDPE < HDPE < UHMWPE

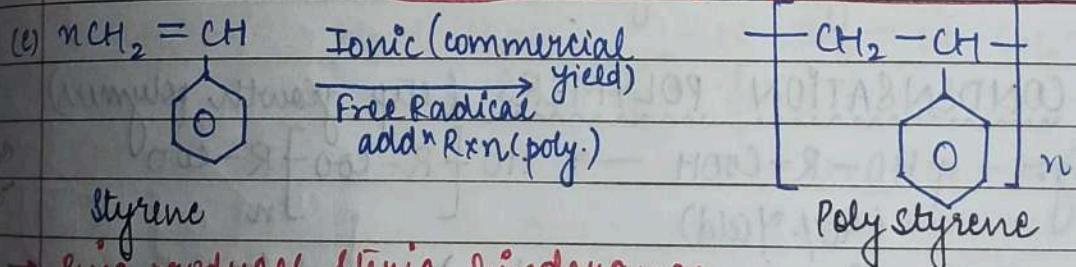


Glass Transition Temp (GTT)

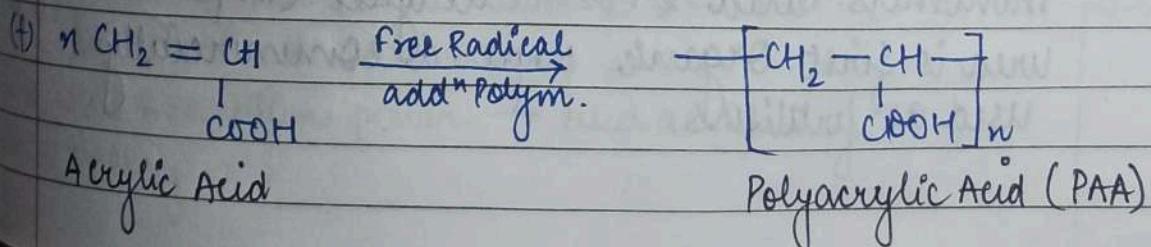
Prop of plastic :- Temp above which behaves like soft rubber, below which behaves like hard plastic

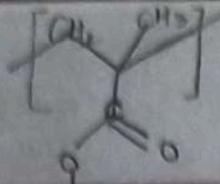
Absent work

Date :- 2 Dec, 2022

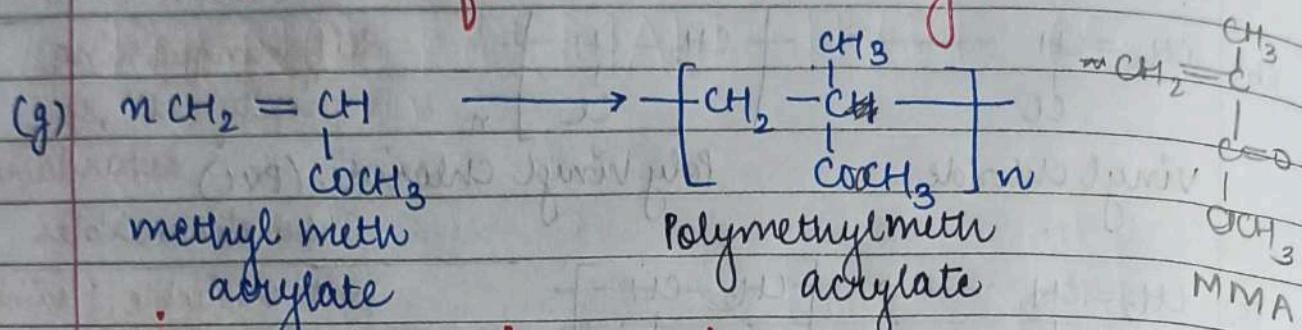


- Ring produces steric hindrance
- syn-diastatic \Rightarrow crystalline \rightarrow tough & hard
- Laboratory instruments

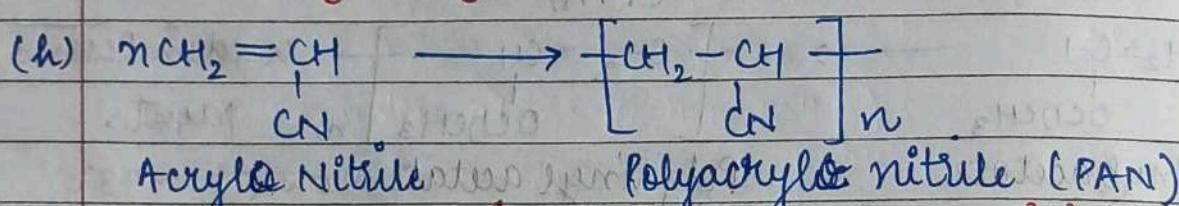




- Crystalline arrangement
- Not as hard & tough as compared to Polystyrene (PS) due to presence of carboxylic acid.
- Water soluble
- Adhesive, artificial tears, treat dry ice.

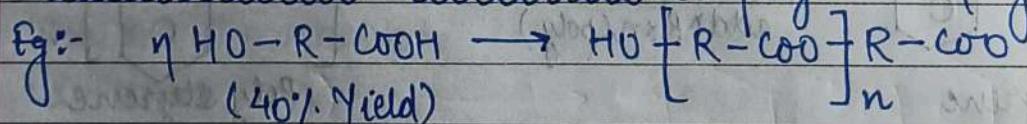


- Highest RI (Refractive Index)
- Hard & Regularly arranged



- Due to CN bonding (Strong due to EN diff), it is resistant to solvent.
- Used to make fibres.
- Used to make textiles & technological items.
- Fibre Strength is > Nylon

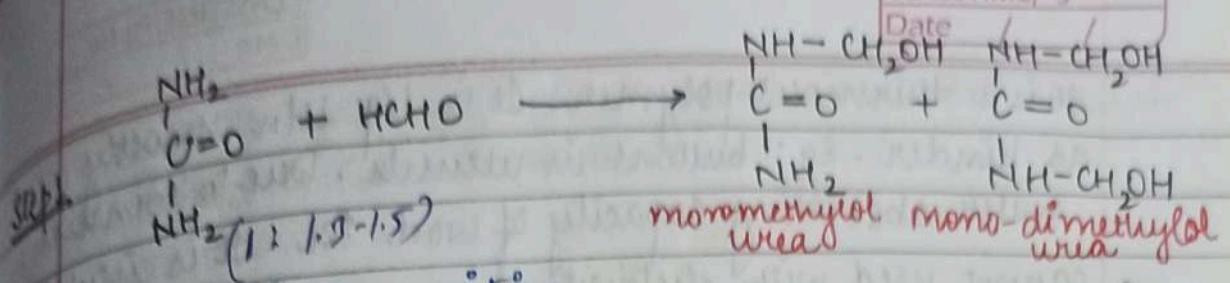
CONDENSATION POLYMERS (step growth polymers)



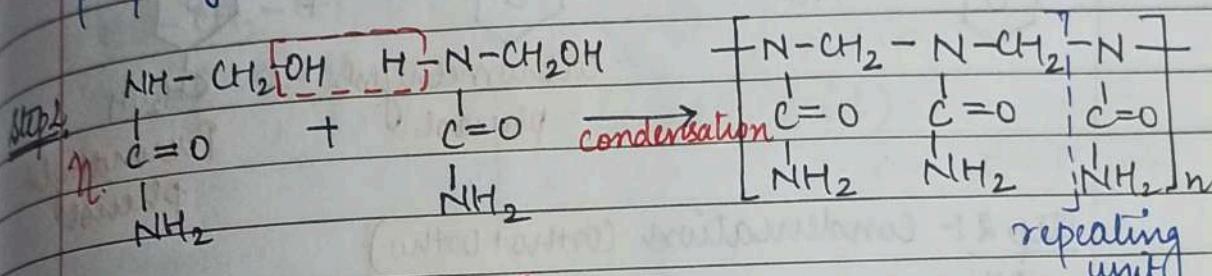
(Not for theory syllabus) + (n-1) H₂O

(a) Urea Formaldehyde :- (Resins)

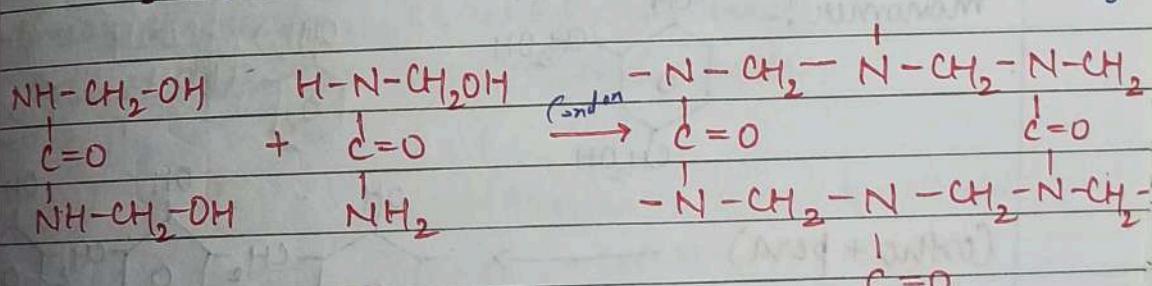
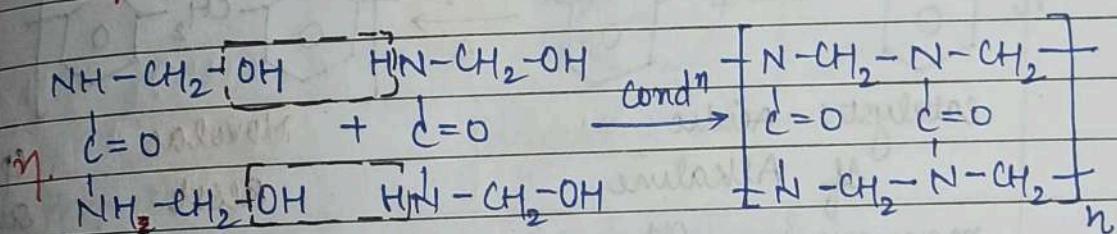
It is a co-polymer. Formed by condensation of 2 monomers Urea & Formaldehyde (Bi-functional grp) Urea is first organic prepared commercially. Used as fertilisers.



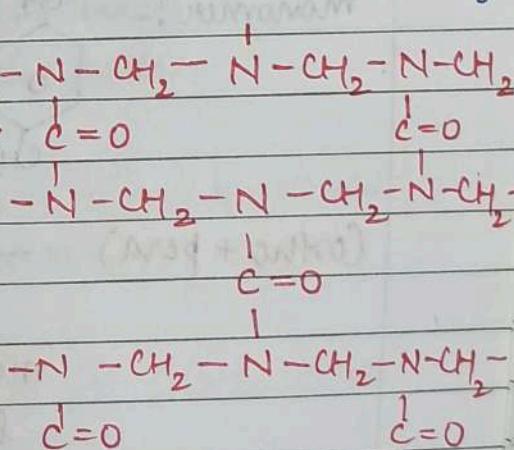
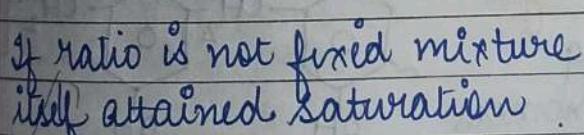
- Step 1 is simply addition
- Ratio of product depend on ratio of monomer but 1st is more in %.
- If HCOH is more \rightarrow deforms more.
- If ratio changes, hardness property changes therefore we take standard ratio for desirable property.



Step 2 is condensation



Cross linking is formed when mixture is taken.



- water absorption power → used as Resins
- Crockery

It is a thermosetting polymer. It is liq soln mostly used as binder. Eg:- buttons in utensils. Due to Binders, water absorbing capacity of wool increases. It is insulator.

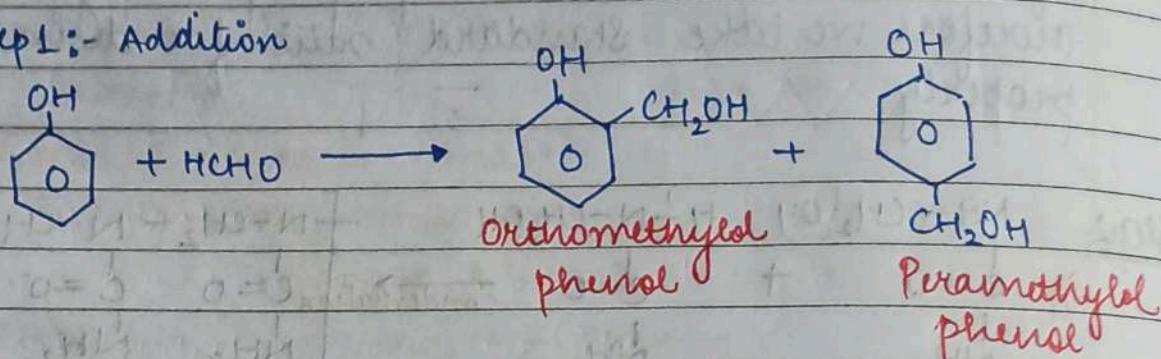
→ cannot used with electricity.

→ 5 Dec 2022

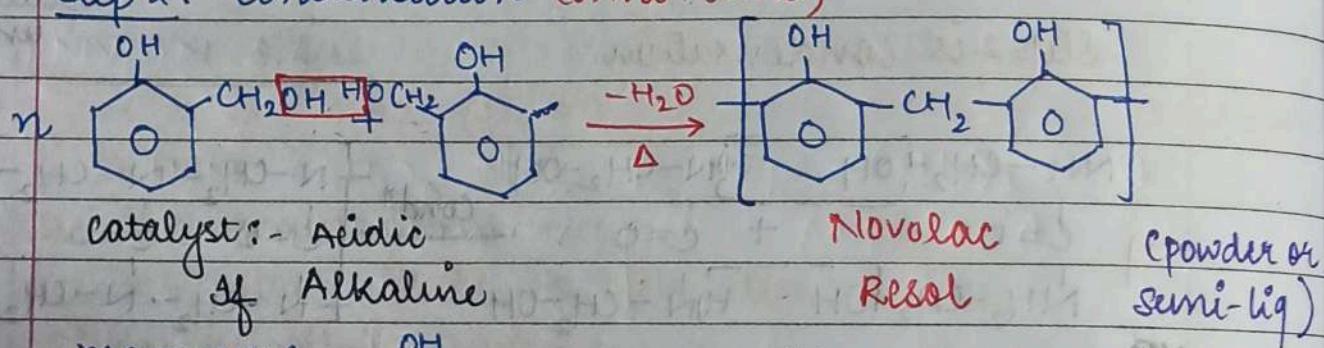
PHENOL FORMALDEHYDE (Resin) (PF)

common name :- Bakelite

Step 1:- Addition



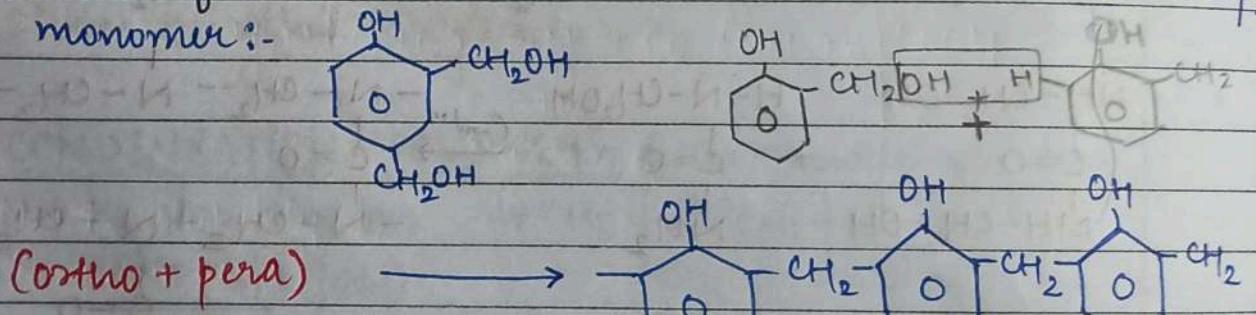
Step 2:- Condensation (ortho+ortho)



Catalyst:- Acidic

If Alkaline

monomer:-

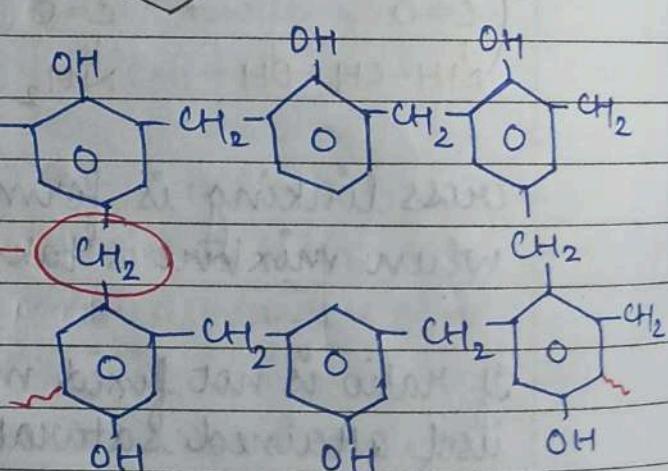


(Ortho + para)

methylene
linkage

→ extent of crosslinking
× percentage of monomers

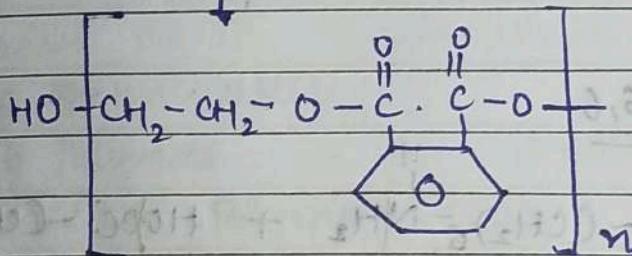
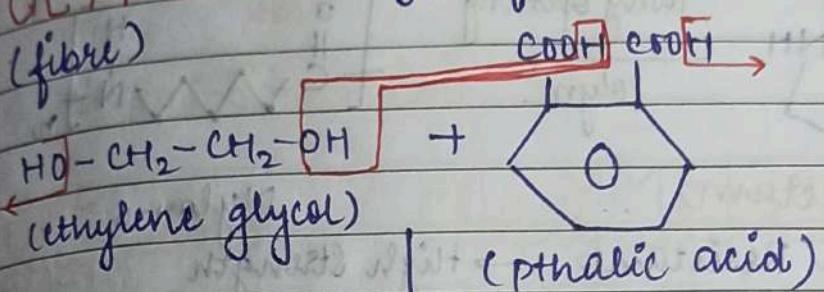
→ Thermo setting.



- zero water absorbing power. Good insulator, used in electrical switches & boards.

GLYPTAL (Type of Polyester)

(fibre)



Glyptal

Properties

- linear or crosslinked (using hardener)
 - Thermosetting & Thermoelastic both.

NYLON :- (polyamides)

Amide linkage -CONH-

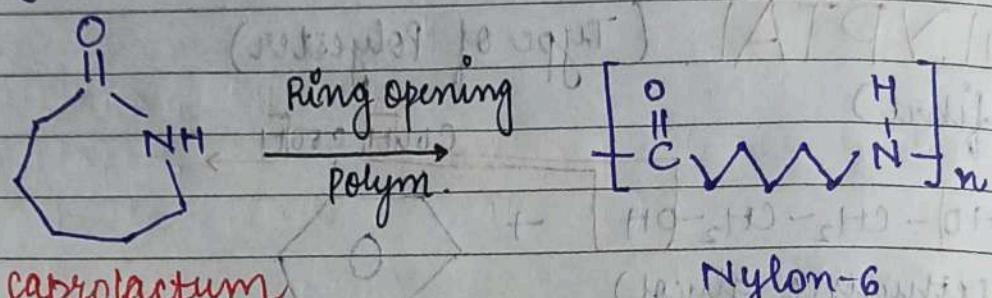
- Thermoplastic
 - High strength
 - Chemical / solvent resistant
 - Used as fibre.

Types of Nylons (copoly)

- (a) Nylon - 6 (Homo)
- (b) Nylon - 6, 6
- (c) Nylon - 6, 10 (copoly)
- (d) Nylon - 6, 11 (Homo)
- (e) Nylon - 12 (Homo)
- (f) Nylon - 6, 12 (copoly)

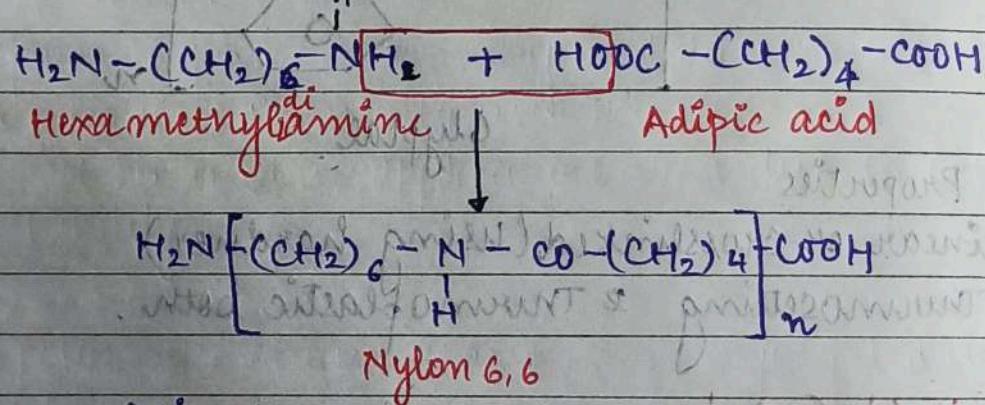
(A) NYLON 6

Ring opening (Caprolactum) polymerisation



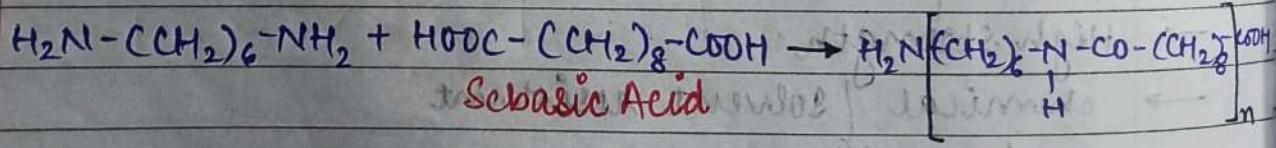
- low water resistance → high strength
- Sports articles → fibre

(B) NYLON - 6, 6

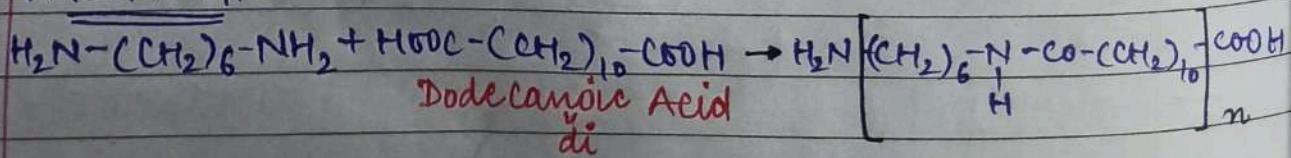


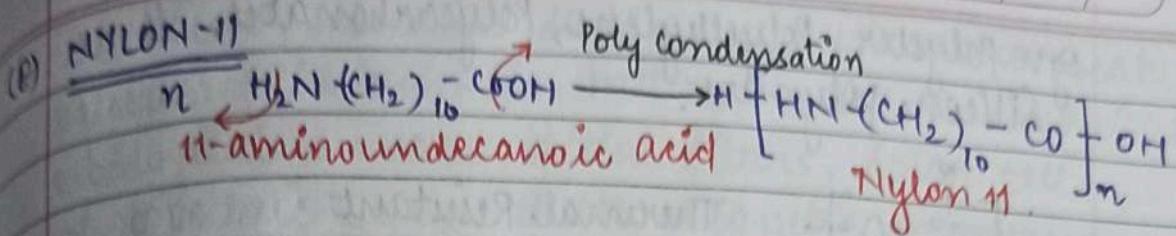
- MW ↑, Solubility ↑

(C) NYLON - 6, 10

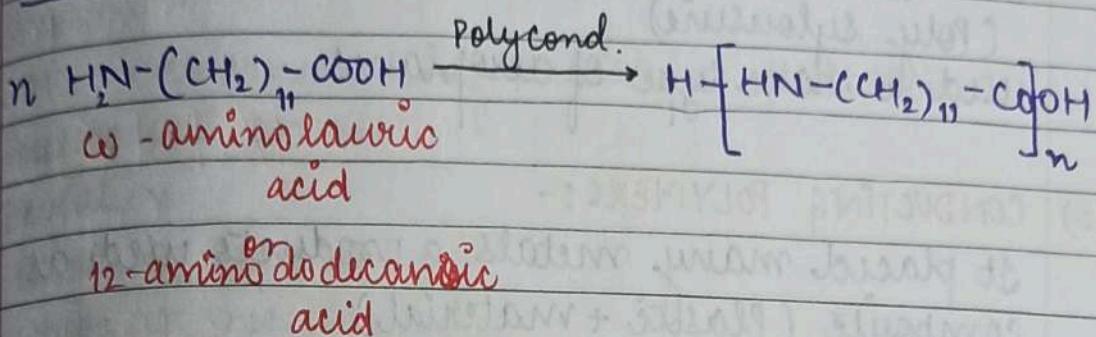


(D) NYLON - 6, 12





(P) NYLON-12



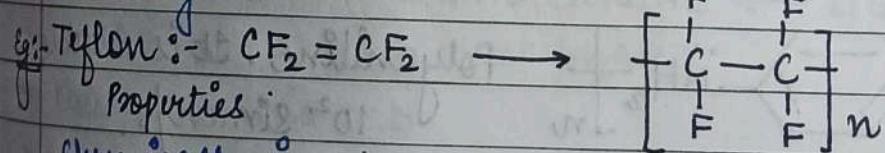
SPECIALITY POLYMERS :-

used in high performance area & in engineering materials.

- (1) Engineering Thermoplastics.
- (2) Conducting Polymers.
- (3) Electromagnetic Polymers (ECP)
- (4) Liquid Crystalline Polymers (LCP)
- (5) Biodegradable polymers.

(A) Engineering Thermoplastics :-

linear or branched, structure, chemical resistant, high thermal & mechanical strength, high oxidation stability.

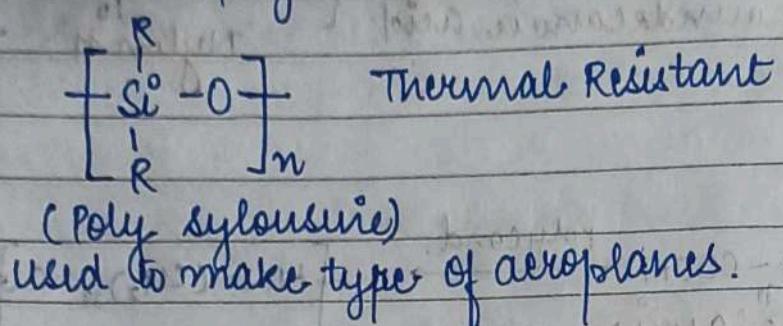


Properties :- chemically inert, Abrasion Resistant high used in laboratory materials

Tapes

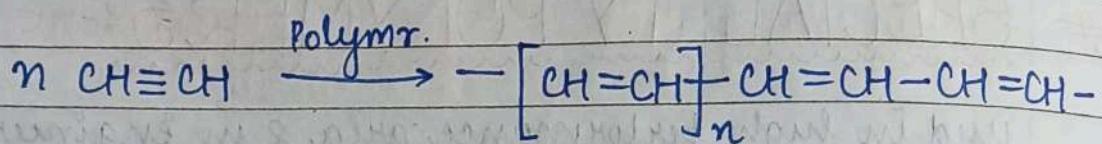
UV stability

Eg:- Polyester, Polyethylene, Polycarbonates, some Silicon polymers.



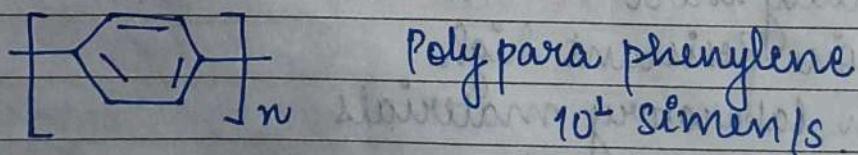
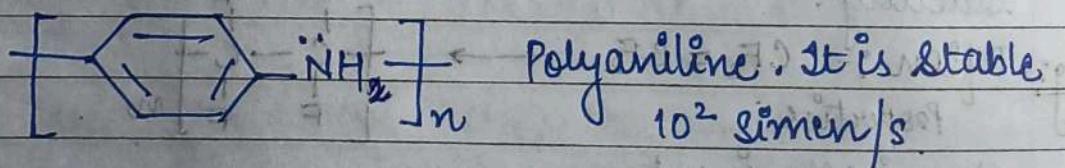
(B) CONDUCTING POLYMERS :-

It placed many metals & products used as composite (Plastic + material)



- (a) Due to alternate single - double bond conducting occurs.
- (b) It is delocalized system.
- (c) Organic doping is done by oxidation & reduction.
- (d) It is environmentally unstable.
- (e) cannot be used in application area due to oxidation instability.

If polymeric chain have π -conjugated delocalised system.



It is inert, oxidation stable, used in rechargeable batteries (lithium-ion battery), used as chemical & biological sensors, optical filters, solar cells, photovoltaic cell & Electromagnetic interference shielding ~~EMI~~

EMI :- Modern type of radiation pollution
methods to prevent

- (a) Deviation
- (b) Block at source end
- (c) Block at receiver end.

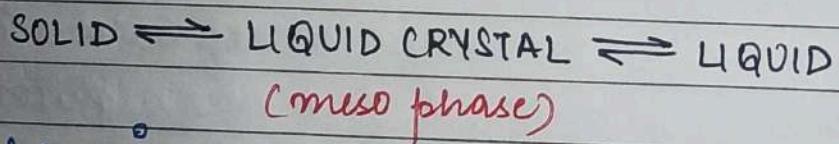
(d) ELECTROLUMINESCENT POLYMERS (ECP) :-

some can be used as luminous material. In some polymers band gap is low. Due to low gap charges, start glow.

(PLED/OLED) :- Polymer or Organic light emitting diode.

(e) LIQUID CRYSTALLINE POLYMER:-

Some polymer in nature are in highly crystalline form. But when ↑ temp & conc. changes & then it convert into



Meso phase in LCD.

(f) BIO-DEGRADABLE POLYMER:-

Some polymers are biologically degraded, by action of micro-organisms in soil.

THERMAL + BIODEGRADATION :-

Due to high temp, small chain form

HYDROLYSIS + BIODEGRADATION :-

Exception polymers, soluble in water.

Eg:- Starch, cellulose, Polybutyrate, Polycaprolactone,
polylactic acid.

UNIT - 1

FUELS

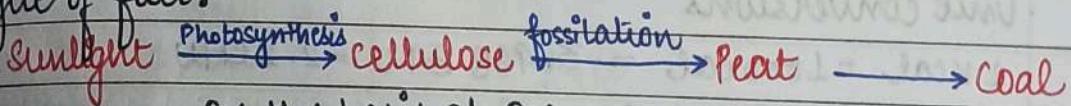
- Fractional distillation of crude oil gives gasoline with less calorific value.
- cracking of higher fractions (more no of c) to produce high calorific value. Two types of cracking = Thermal & hydrolytic

FUELS :- Any substance that produce heat or combustion & used for domestic & commercial purpose.

e.g. wood, coal, Petrol, etc.

- * When we burn fuel in presence of O_2 the covalent bonds break & energy produces.
- some fuels like nuclear fuels (uranium) produces energy w/o O_2 .

Cycle of fuel :-



On the basis of occurrence

PRIMARY :- Derived directly from earth crust (Direct use)

Solid :- coal, wood, Peat

Liquid :- Crude oil

Gas :- Natural gas

SECONDARY :- Used after long chemical processing of primary fuel

Solid :- coke, charcoal

Liquid :- Petroleum, Kerosene

Gas :- CNG, LPG

Liq & gas Secondary fuels are generally used in automobile

CALORIFIC VALUE :-

Quantity of heat liberated when a unit (mass/volume) of fuel is burnt completely & unit of calorific value is different for different types of fuels

units	Solid, liquid	Gas, volatile liq.
CGS	cal/g	calorie/cm ³
MKS	Kcal/kg	Kcal/m ³
BTU	British Thermal unit/lb	BTU/feet ³
CHU	centigrade Heat unit/lb	CHU/feet ³

- (a) Calorie :- Amount of heat required to raise the temp of 1g of water to 1°C
- (b) BTU :- Amt. of heat required to raise the temp of 1 pound of water to 1F.
- (c) CHU :- Amt. of heat required to raise the temp of 1 pound of water to 1°C.

Unit conversions

$$1 \text{ Kcal} = 1000 \text{ cal} = 3.968 \text{ BTU} = 2.2 \text{ CHU}$$

$$1 \text{ cal} = 4.185 \text{ J} = 1.87 \times 10^5 \text{ ergs.}$$

(A) Gross calorific value / Higher Calorific Value :-

(GSV)

(HCV)

when we heat the fuel and allows it to cool down to room temp i.e. 15°C, then it has high calorific value.

(B) Net calorific value / Lower Calorific value :-

(NCV)

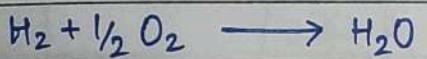
(Lcv)

when we heat the fuel & allows it to cool down to 15°C then some water vapours & gases escape due to which extra amount of heat i.e. heat of vapourisation.

→ G.C.V :- Amount of heat liberated when a unit quantity fuel is burnt in presence of O_2 & products of combustion are cool down to room temp and all fuels have some H_2 thus due hydrocarbon chain (H_2, N_2, S) after combustion hydrogen convert to steam and upon cooling these steam condensed into water so some latent heat is evolved in this process. In GCV, this latent heat is also included so it is higher than LCV.

→ N.C.V :- Net heat produced when a unit quantity of fuels is burnt completely & the products of combustion are allowed to escape. So it is lower than G.C.V

$$N.C.V = G.C.V - \text{latent heat of water vapour}$$



2 18

1 part 9 part

$$\text{Total amount of heat} = 9H \quad (H = \text{amt of water})$$

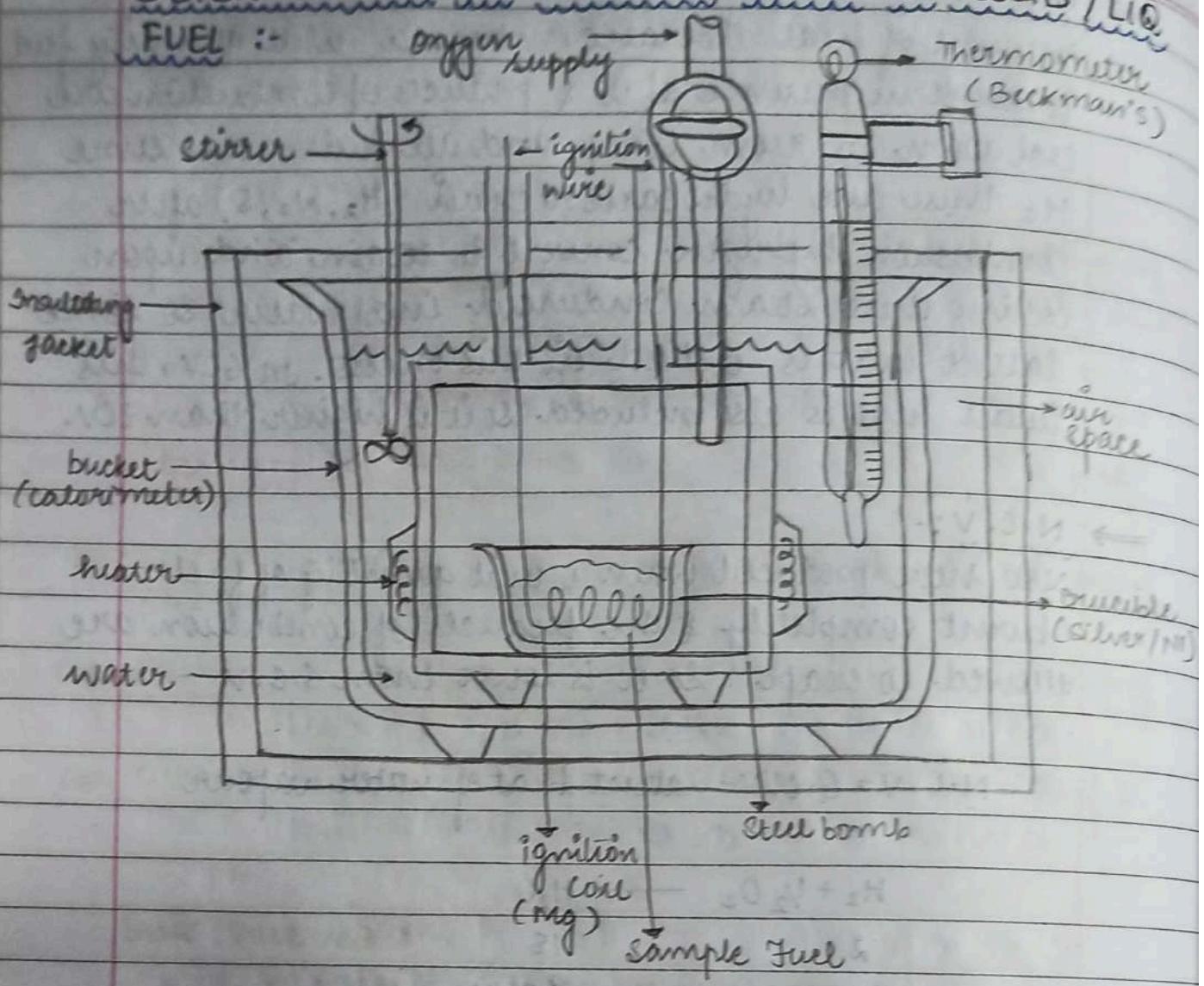
$$N.C.V = H.C.V - 9 \times H \times 587 \text{ (Latent heat) cal/g}$$

Example :- Let % of hydrogen is H%.

% of water is 9H

$$\text{Weight / Amount of water per g} = \frac{9H}{100}$$

→ DETERMINATION OF CALORIFIC VALUE OF SOLID / LIQ. FUEL :-



Let weight of fuel taken = x g

weight of water in calorimeter = w

water equivalent of instrument = w

(calorimeter, stirrer) $(M_1 S_1 + M_2 S_2 + \dots)$

Water equivalent weight = $M \cdot S$

Initial temp = t_1 °C

Final temp = t_2 °C

Let GCV of fuel = C cal/g

[w = heat capacity = weight \times specific heat capacity]

Principle of Calorimetry
Heat lost = Heat Gain

$$\text{Heat lost} = \alpha C \text{ cal} \rightarrow ①$$

$$\begin{aligned}\text{Heat gained by water} &= W \times \Delta T \times \text{specific heat} \\ &= W(t_2 - t_1) \times 1 \\ &= W(t_2 - t_1)\end{aligned}$$

$$\text{Heat gained by equipment} = w(t_2 - t_1)$$

Water equivalent is the no. of ^{used} calories to heat the equipment

$$\text{Total Heat gained} = (W+w)(t_2 - t_1) \rightarrow ②$$

$$\alpha C = (W+w)(t_2 - t_1)$$

$$C = \frac{(W+w)(t_2 - t_1)}{\alpha}$$

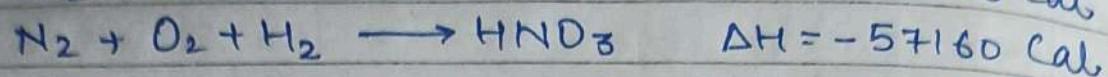
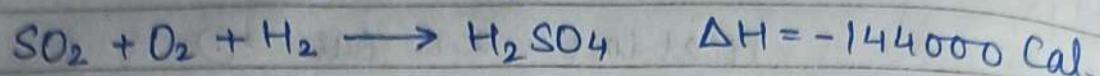
$$N.C.V = G.C.V - H \times 587 \text{ cal/g}$$

→ corrections

- (a) fuse wire correction (F_c)
- (b) Acid correction (A_c)
- (c) cooling correction (C_c)

(d) The amount of heat liberated by diffusion of fuse wire must be subtracted.

(e) In presence of O_2 , Sulphur & Nitrogen oxidise very small amount in bomb.



(These are exothermic reactions)

It means some amount of heat is released in bomb.

- * For each mL of N/10 H_2SO_4 formed, 3.6 cal should be subtracted.

- * For each mL of N/10 HNO_3 formed, 1.43 cal should be subtracted.

(3) Even after by applying thermal insulation outside, some heat is lost in surrounding due to which the heat practically achieved is lower than theoretical cal

If time taken for cooling is t min with cooling rate of $\frac{dt}{\text{min}}$ then cooling correction

= adt that should be added to final temp.

i.e

$$G.C.V = \frac{(W+w)(t_2 - t_1 + C_c)}{x} - (F_c + A_c)$$

Q. 0.5 g sample of naphthalene is burned in bomb calorimeter containing 650 g. of water at an initial temp of 20°C . The final temp achieved was 26.4°C . The heat capacity of calorimeter is $420 \text{ J}/^\circ\text{C}$

$$G.C.V = \frac{(W+w)(t_2 - t_1)}{x}$$

x = weight of fuel = 650g 0.500g

t_1 = initial temp = 20°C

t_2 = final temp = 26.4°C

Heat (specific) of water = 4.184 J/g°C

weight of water = 650g

$$W = (650 \times 4.184) \text{ J}/\text{°C}$$

$$= 2719.6 \text{ J}/\text{°C}$$

w = heat capacity of calorimetry = 420 J/°C

x = 0.500g

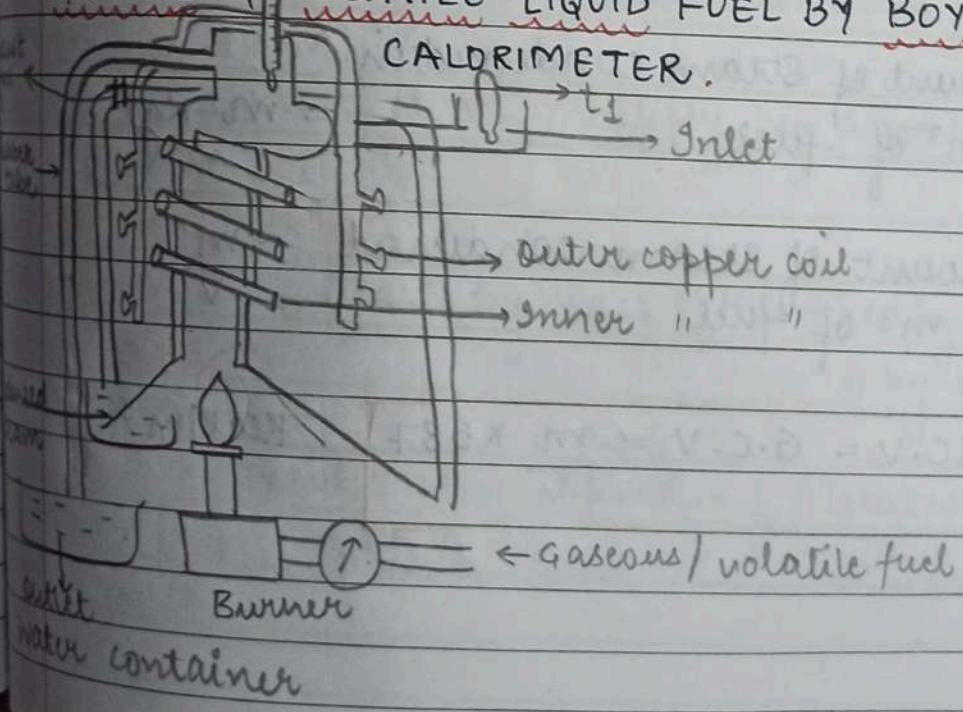
Applying formula;

$$G.C.V = \frac{(2719.6 + 420)(26.4 - 20)}{0.5}$$

$$= 40,186.88 \text{ cal/g}$$

Date: 13 Dec, 2022

→ DETERMINATION OF CALORIFIC VALUE OF FUELS FOR
GASEOUS & VOLATILE LIQUID FUEL BY BOY'S GAS
CALORIMETER.



Volume
 Let velocity of gas burnt at STP in time $t = v \text{ m/s}$
Weight of
maximum water heated up in time $t = w \text{ kg}$
wt of steam condensed in time $t = m \text{ kg}$

Initial inlet temp $= t_1^\circ \text{C}$

Final outlet temp $= t_2^\circ \text{C}$

Let G.C.V = $c \text{ Kcal/m}^3$

Heat lost = heat gained (Principle of Calorimetry)
 $c.v = \text{Total heat lost by fuel (lost) produced}$

Heat gained by water = $m \cdot \Delta t \cdot \text{specific heat of water}$
 $= w(t_2 - t_1)$

$$c.v = w(t_2 - t_1)$$

$$\boxed{G.C.V = c = w(t_2 - t_1)} \quad \text{Unit} = \text{Kcal/m}^3$$

Amount of steam condensed in
 $v \text{ m}^3$ of fuel $= m \text{ kg}$

Amount of steam condensed $= \frac{m}{v}$
 per m^3 of fuel

$$\boxed{N.C.V = G.C.V - \frac{m \times 587}{v}} \quad \text{Kcal/m}^3$$

→ THEORETICAL CALCULATION OF
CALORIFIC VALUE:-

By Dulong's FORMULA

(H, C, S are combustible)

(N = non combustible)

(O = supports burning, combines with H to form water $\Rightarrow \downarrow$ N.E.V)

calorific value	elements
8080 Kcal/Kg	C
34500 Kcal/Kg	H
2240 Kcal/Kg	S

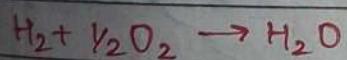
Available Hydrogen ↑

$$\text{Dulong's formula} = \frac{1}{100} \times [8080C + 34500(H - \frac{O}{8}) + 2240S]$$

unit = Kcal/Kg

Here, C, H, O, S are % of these elements present in fuel.

(If Kg is given, don't multiply by 1/100 in formula)



2 → 16 2 parts by mass of H is fixed by 16 parts of O by mass

$$\left\{ \text{Total amt of H fixed} = \frac{1}{8} (\text{Total wt of O}) \right\}$$

Date : 14-12-2022 coal

Q1. A sample of oil contains 92% C, 5% H and 3% Ash content. When this coal was tested for its calorific value in Bomb Calorimeter, following results are obtained.

$$\text{Weight of Coal burnt} = 0.95 \text{ g}$$

$$\text{Weight of water taken} = 700 \text{ g}$$

$$\text{Water equivalent of bomb & calorimeter} = 2000 \text{ g}$$

$$\text{Increase in temp} = 2.48^\circ\text{C}$$

$$\text{Acid correction} = 60 \text{ cal} = A_c$$

$$\text{Cooling correction} = 0.02^\circ\text{C} = C_c$$

$$\text{Fuse wire correction} = 10 \text{ cal.} = F_c$$

$$\text{Cal. NCV & G.C.V of fuel, Latent heat of steam} \\ = 587 \text{ cal/g.}$$

A1. 92% C, 5% H, 3% Ash

$$W = \cancel{0.95 \text{ g}} \quad 700 \text{ g}$$

$$W = 2000 \text{ g}$$

$$T_2 - T_1 = 2.48^\circ\text{C} ; x = 0.95 \text{ g}$$

$$C = \frac{(W+w)(T_2-T_1)}{x}$$

$$= (W+w)(T_2-T_1 + C_c) - (A_c + F_c)$$

$$= \frac{\cancel{(700+2000)}(2.48+0.02) + (60+10)}{0.95}$$

$$= \frac{(2700)(2.50) + 70}{0.95}$$

$$= \frac{-3250 + 70}{0.95} = \frac{-3180}{0.95} = 3$$

$$= 7031.57 \text{ cal/g}$$

$$G.C.V = 7031.6 \text{ cal/g}$$

$$N.C.V = 67031.6 - \frac{9(H\%) \times 587}{150} = 6767.45 \text{ cal/g}$$

During det. of cal. value of gaseous fuel, results:-
 vol of gaseous fuel burnt = $0.098 \text{ m}^3 = V$
 weight of water used for cooling = $50 \text{ kg} = W$

weight of steam condensed = 0.051 kg

inlet water temp = 26.1°C

outlet " " = 46.5°C

cal gcv & LCV

$$G.C.V = \frac{W(t_2 - t_1)}{V}$$

$$= \frac{50(46.5 - 26.1)}{0.098} = 10,408.16 \text{ Kcal/m}^3$$

$$N.C.V = G.C.V - \frac{0.051 \times 587}{0.098}$$

$$= 10,408.2 - 0.52 \times 587$$

$$= 10,408.2 - 305.47$$

$$= 10,102.73 \text{ Kcal/m}^3$$

Q3. A coal sample has following composition by wt

C = 92%

O = 2%

S = 0.5%

N = 0.5%

Ash = 1.5%

NCV of coal was found to be 9430 Kcal/kg

Cal %. of H in fuel & its higher calorific value.

$$NCV = G.C.V - \frac{9H}{100} \times 587$$

$$G.C.V = N.C.V + \frac{9H}{100} \times 587$$

$$= 9430 + \frac{9H}{100} (587) - \textcircled{i}$$

Acc to Douglas formula

$$G.C.V = \frac{1}{100} [8080.C + 34500(H-O) + 2240S]$$

$$C = 92, D = 2, S = 0.5$$

$$G.C.V = \frac{1}{100} [8080(92) + 34500\left(H-\frac{2}{8}\right) + 2240(0.5)]$$

$$= 7433.6 + 345\left(H-\frac{1}{4}\right) + 11.2$$

$$= 7433.6 + 86.25 + 11.2 + 345H$$

$$= 7531.05 + 345H - \textcircled{ii}$$

$$\textcircled{i} = \textcircled{ii}$$

$$9430 + 52.83H = 7531.05 + 345H$$

$$-(345 - 52.83)H = 7531.05 - 9430$$

$$(292.17)H = 1898.95$$

$$H = \frac{1898.95}{292.17} = 6.49$$

$$H = 6.5\%$$

SOLID FUELS

Primary fuel :- (Solid fuels) coal, peat.

secondary :- coke, charcoal (solid fuels)

Destruction of vegetation under high pressure & temp makes coal. → Microorganism attack or Temp & press

Biological :-
cellulose $\xrightarrow{\text{Microorg}}$ Peat
(in plants)

Metamorphism :- (chemical step)

Peat → coal → Bituminous → Anthracite
(brown) (Black)
(coalification) C amount inc →

Bituminous $\xrightarrow[\text{Wt O}_2]{\Delta}$ COKE

Wt :- N, S, H, O, C (different amount)

Approximate Test.

moisture

volatile

Carbon

ash

Ultimate analysis

C, N, O, S exact

percentage.

(Known wt of coal $\xrightarrow{\Delta 105-110^\circ \text{C}}$ moisture + coal)

$$C = \frac{\text{Total weight}}{\text{Moisture} + \text{Volatile} + \text{ash}}$$

Composition Moisture + volatile + ash

Approximate Analysis

① Moisture content

Method:-

Moisture content is det by heating known amt of

coal at $105-110^{\circ}\text{C}$ in a hot air oven for about 1 hour. Then it is cooled in a desiccator & weighed.

$$\% \text{ moisture content} = \frac{\text{weight loss}}{\text{original wt}} \times 100$$

Desiccator \rightarrow Dehydrating salt

Drawbacks & Significance

(a) Only for low moisture content (5-10) (for good fuel).

(b) During combustion, If no moisture is present, more fly ash.

(2) Volatile Analysis :-

The coal consists of various gaseous & liquid volatile material after complete combustion of coal. For eg: H, CO, CH_4 , Hydrocarbons excluding moisture. It is det. by heating known wt of moisture free coal sample in covered Pt crucible at $950 \pm 20^{\circ}\text{C}$ for 7 mins. then cooled & weigh.

$$\% \text{ volatile content} = \frac{\text{loss in wt}}{\text{wt of coal (original)}} \times 100$$

Drawbacks

- (a) ↑ volatile \rightarrow more smoke as.
- (b) 20-30 % volatile \rightarrow in bituminous coal

(3) Ash Content :-

Due to chemical Reaction during comb. the org. substances like (present in coal) Si, Al, iron oxide, lime, magnesia $\text{Mg(OH}_2\text{)}$, etc (Aluminia)

converted into ash. It is det. by Δ the residue left after volatile analysis, at $700 \pm 50^\circ\text{C}$ for half an hour w/o covering. then cooled & weight.

Drawback

less Ash \rightarrow x contribution in G.C.V / N.C.V

Pollution

$$\% \text{ Ash content} = \frac{\text{weight of residue left} \times 100}{\text{wt of coal}}$$

Fixed Carbon :-

$$\% \text{ C} = 100 - (\% \text{ Mois} + \% \text{ volatile} + \% \text{ ash})$$

Date :- 16 Dec, 2022.

Q. A sample of coal was analyse as follows :- exactly 2.0g of coal was weight into a silica-crucible. After heating for one hour at 110°C , the residue weight 1.975g. The crucible next was covered & heated for 7 min at 950°C . The residue wt 1.328g. The crucible was then heated w/o the cover until a constt wt was obtained. The last residue left was 0.205g. Cal the % result of above analysis

A) Initial wt = 2g

$t = 1 \text{ hr}; T = 110^\circ\text{C}; \text{wt left} = 1.975 \text{ g}$

then $t = 7 \text{ min}; T = 950^\circ\text{C}, \text{wt left} = 1.328 \text{ g}$

$t = \text{constt. heated w/o cover}; \text{wt left} = 0.205 \text{ g}$.

(1) Moisture = $\frac{\text{wt loss}}{\text{Original}} \times 100 = \frac{2 - 1.975}{2} \times 100 = 1.25\%$

$$(2) \text{ volatile \%} = \frac{\text{wt loss}}{\text{Original}} \times 100 = \frac{1.975 - 1.328}{2} \times 100 \\ = 32.8\%.$$

$$(3) \text{ Ash \%} = \frac{\text{residue}}{\text{Original}} \times 100 = \frac{0.205}{2} \times 100 = 10.25\%.$$

$$(4) \text{ carbon \%} = 100 - (1.25 + 32.6 + 10.25) \\ = 54.9\%.$$

ULTIMATE ANALYSIS :-

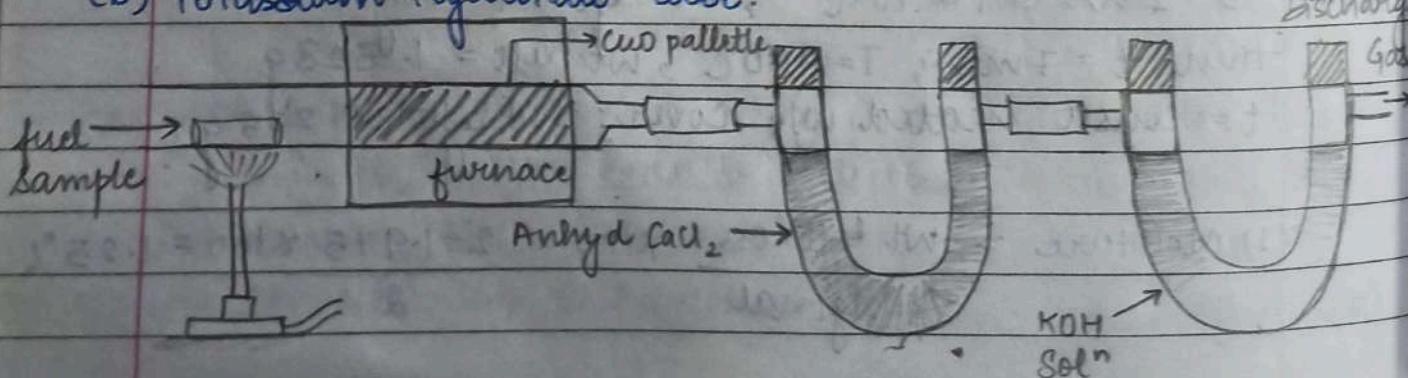
By these analysis, we measure \% of C, N, S, O etc elements. It is important bcz it defines the calorific value of coal. Carbon gives max. calorific value therefore more carbon content means more calorific value. N does not give any calorific value but it forms by products which is useful (NH_3 , NH_4OH). S is important, it contributes in calorific value. More S is harmful bcz it causes pollution (oxides of sulphur). More O means more fixing of H. more H more calorific value.

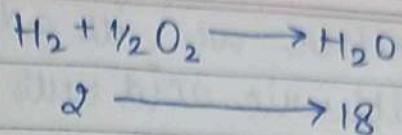
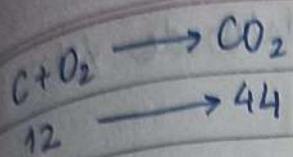
Determination of carbon & hydrogen in Coal :-

They are determined by passing combustion products through two types of V-Shaped tubes i.e.

(a) Anhydrous calcium chloride tube

(b) Potassium hydroxide tube:





The total water vapours formed i.e. estimated by passing through anhydrous $CaCl_2$ tube because $CaCl_2$ absorbs all water vapours.



Let wt of vapours formed (absorbed in $CaCl_2$) is x g.

then 18 g of H_2O contains $\frac{2}{18}$ g of H_2O
 x g of H_2O contains $\frac{x}{18} \times 2$

$$\boxed{\% \text{ of } H_2 = \frac{2}{18} \times \frac{x}{\text{wt of coal taken}} \times 100}$$



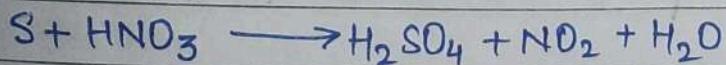
Let wt of total CO_2 released is y grams

44 g of CO_2 contains 12 g of C
 y g of CO_2 contains $\frac{12}{44} \times y$

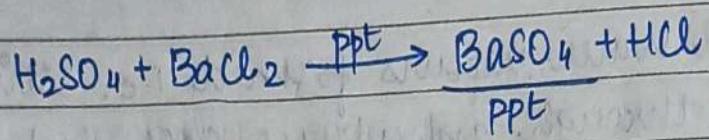
$$\boxed{\% \text{ of } C = \frac{12}{44} \times \frac{y}{\text{coal wt}} \times 100}$$

* Estimation of Sulphur in Coal :-

Sulphur can be estimated by passing nitric acid fumes through the coal. All the sulphur present in the coal react with nitric acid to form sulphuric acid.



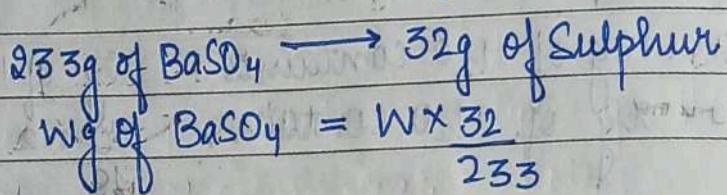
Further we will add barium chloride solⁿ to,
Sulphuric acid will ppt as BaSO₄.



NOW BaSO₄ ppt dried & weight.

$$\text{wt of BaSO}_4 = 233 \text{ g}$$

let wt of BaSO₄ formed be Wg



$$\% \text{ of Sulphur} = \frac{W \times \frac{32}{233} \times 100}{\text{wt of Coal taken}}$$

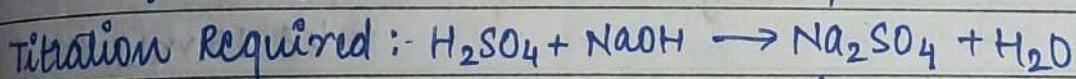
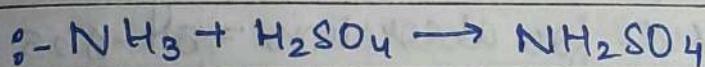
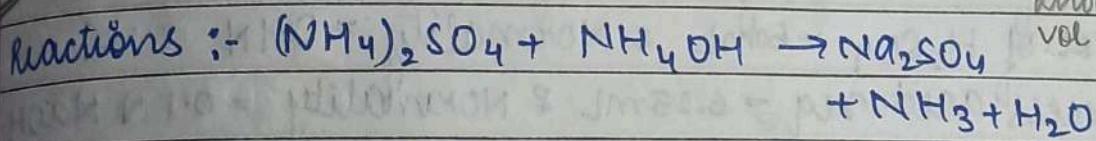
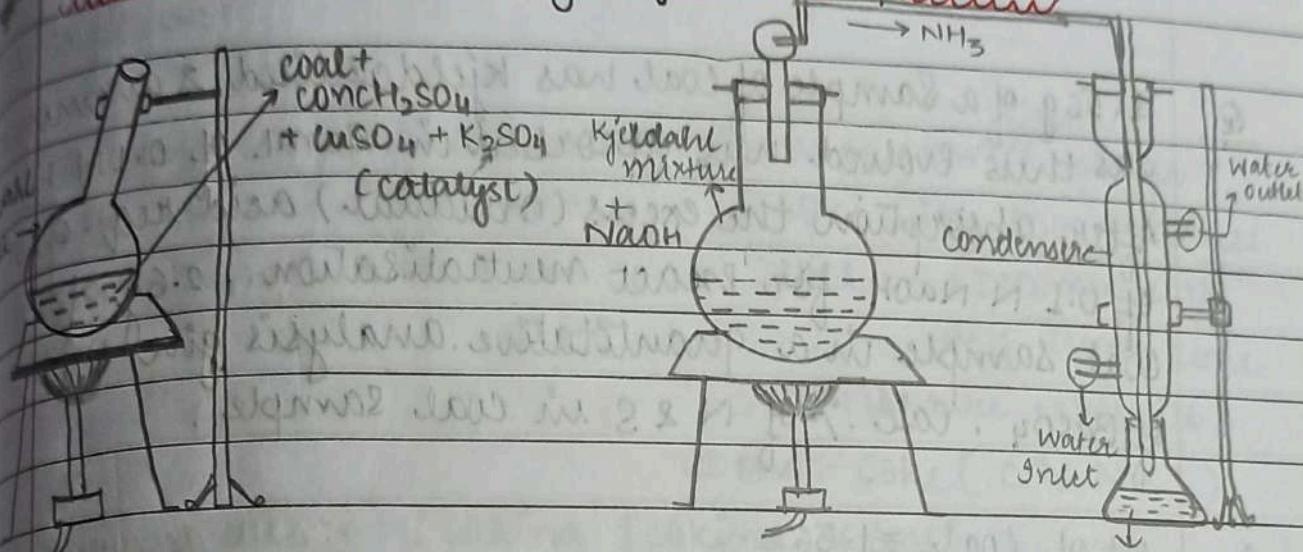
Another method is in Bomb calorimeter which is used to calculate sulphur by washing the bomb with distilled water & collecting the Sulphuric acid formed there & add BaSO₄ in it.

- Q. 1g of sample of coal was used in a bomb calorimeter for det. of calorific value. C.V of coal was found to be 8800 cal/g. The ash formed in the bomb calorimeter was extracted with acid & the acid extract was heated with a barium nitrate solⁿ. So that ppt of BaSO₄ obtained. The ppt were filtered dried & wt of ppt was found to be 0.08g. calc. the % of the Sulphur in the coal present.

$\text{ppt of } \text{BaSO}_4 = 0.08 \text{ g}$
 $\text{CV} = 8800 \text{ cal/g}$

$$\% \text{ of S} = 0.08 \times \frac{32}{233} \times 100 = \frac{256}{233} = 1.09\%.$$

Extraction of N :- By Kjeldahl process



It is 2 step procedure. In 1st step in Kjeldahls flask we take coal sample & add H_2SO_4 heat for a while.

The N present react with H_2SO_4 to form ammonium sulphate. In 2nd $(\text{NH}_4)_2\text{SO}_4$ heated with (NH_4OH) with release of ammonia then ammonia react with H_2SO_4 . Now if we know how much NH_3 formed we calculate N%. If we find how much unreacted H_2SO_4 left then we know how much H_2SO_4 used then equivalent NH_3 .

To det. the vol. of st. H_2SO_4 used to absorb or neutralise the liberated ammonia.

$$\% \text{ of } N_2 = \frac{N_1 V_1 \cdot 1.4}{\text{wt of coal sample}}$$

N_1 = Normality of Std. H_2SO_4 taken

V_1 = vol. of Std. H_2SO_4 used to absorb ammonia liberated.

Q. 1.56 g of a sample of coal was Kjeldahlised & ammonia gas thus evolved was absorbed in 50 mL of 0.1 N H_2SO_4 . After absorption the excess (residual) acid req. 6.25 mL of 0.1 N NaOH for exact neutralisation. 2.6 g of the coal sample in a quantitative analysis gave 0.1755 g of $BaSO_4$. Calc. % of N & S in coal sample.

A. wt of coal = 1.56 g

Vol. of H_2SO_4 = 50 mL & Normality = 0.1 N

Excess acid req = 6.25 mL & Normality = 0.1 N NaOH

V_1 = acid used for absorption = 50 - 6.25
= 43.75 mL

$$\% \text{ of } N_2 = \frac{0.1 \times 43.75 \times 1.4}{1.56} \cancel{\times 100}$$

$$= 3.926\%$$

For sulphur

Coal wt = 2.6 g ppt = 0.1755 g $BaSO_4$

$$\% S = \frac{0.1755 \times 32 \times 100}{233 \times 2.6}$$

$$= 0.927\%$$

CARBONIZATION OF COAL :-

(Manufacturing of coke)

COKE (Metallurgical coke)

- Highly porous
- High CV
- Light wt
- Hard

coal $\xrightarrow[\text{in abs. of air}]^{\text{high T}}$ coke

(a) Type of carbonization

- (i) low Temp
- (ii) High Temp

$500 - 600^{\circ}\text{C}$

$1000 - 1200^{\circ}\text{C}$

(Discharge gases↑, (volatile↑))

COKE with low qualities

coal $\xrightarrow{\text{decompose at}}$

diff Temp zone

(Moisture \rightarrow volatile)

at end:- coke (C↑; N, S↓)

(b) Types of coal :- (caking / non-caking of coal)

caking coal

Non-caking

Caking :- coal used to make coke. Eg:- Bituminous

Non-caking :- coal " " " ". But it's not good quality. Eg:- Sub-bituminous, lignite, anthracite.

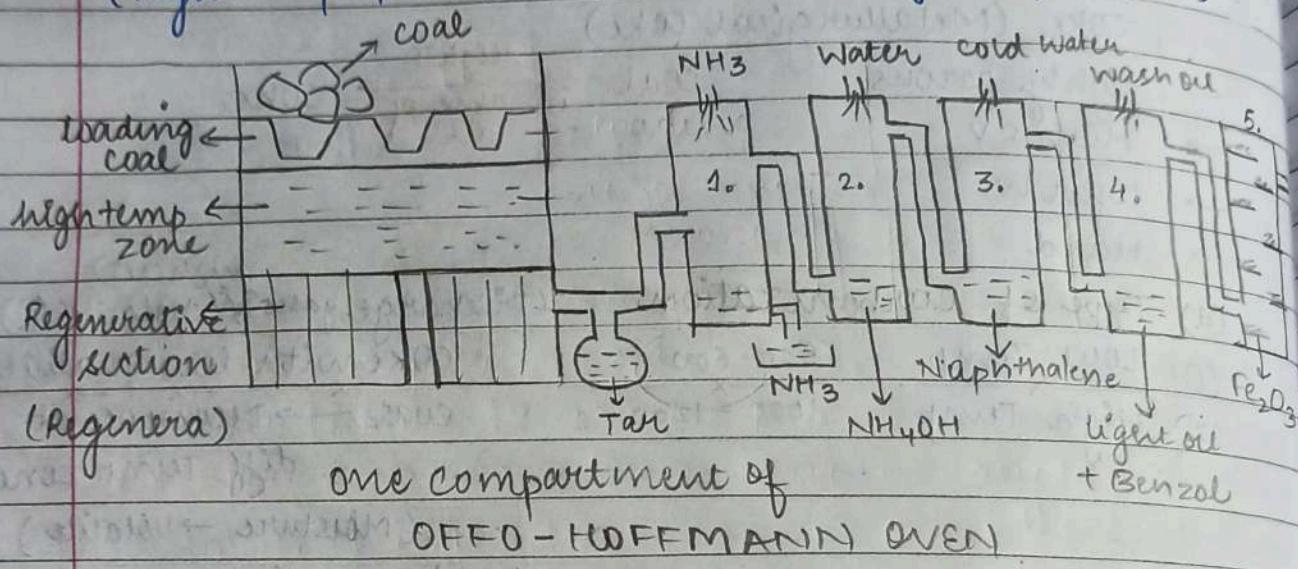
Metallurgy coke :- Extraction of metal, High Temp carbonised coke is used.

- Hardness
- Good bed
- Metals fills in pores.

Manufacturing of coke

(High Temp furnace)

Beehive oven

Offo - Hoffmann oven
(many compartment)

COKE gas :- Mix of CH_4 & Hydrogen + Small amount of $\text{CO}_2, \text{CO}, \text{N}_2, \text{O}_2$

used as gaseous fuel \rightarrow Industry, boilers.

- Mechanism :-

1:- Ammonia washing Tar + Excess lig ammonia

2:- Water used to remove Ammonia.

3:- Aromatic compounds regenerates.

$> 78^\circ\text{C}$ Naphthalene's freezing pt.

4:- wash oil used to separate Benzol.

5:- Mainly 8 compounds (Hydrogen Sulphide) are separated using Fe_2O_3 (catalyst).



\downarrow
manufacturing of
sulphur.

LIQUID FUELS

Kerosine, petroleum (gasoline)

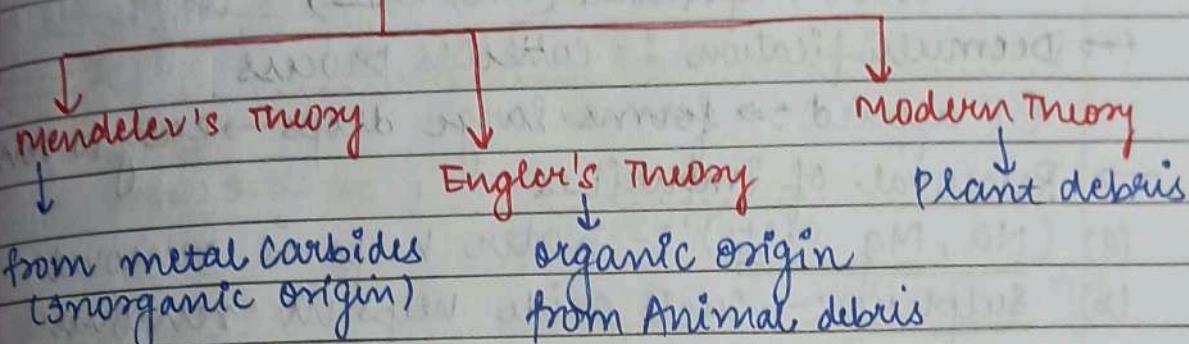
Petroleum:- 4000 kJ/kg cv.

used in combustion engine
 petro → rock oilium → oil

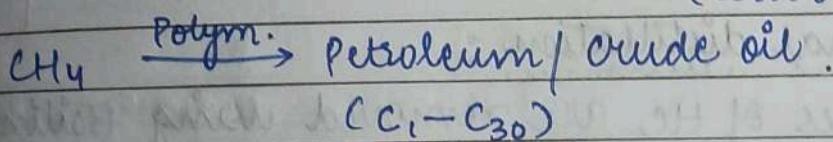
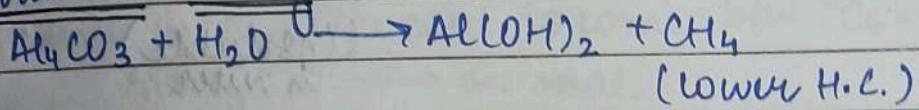
Manufacturing of petroleum :-

Petroleum has (Traces of almost all metals), S, C, N, O, aromatic, etc (haemoglobin & chlorophyll also).

How liquid fuels are prepared :-



(A) Mendeleev's Theory :-



Failed :- S, N, chlorophyll practically found, not in Theory

(B) Engler's Theory :-

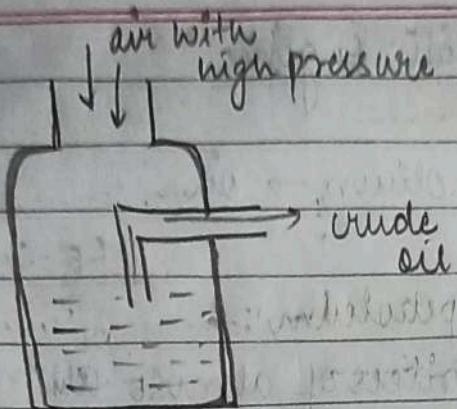
Suggested all components of petroleum

fails :- presence of chlorophyll

Processing of crude oil :-

- Drilling
- Refining

(1) Drilling :-



(2) Refining :-

emulsion, impurities (Na, Ca, S)

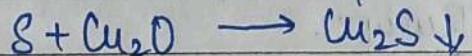
→ Decoagulation :- Cottrell's process

EF applied \Rightarrow forms large drops \rightarrow easy to remove

→ Removal of impurities

(a) (Na, Mg salts) :- Water helps in removal

(b) sulphur :- Cu_2O oxide helps in removal



(insoluble)
in water

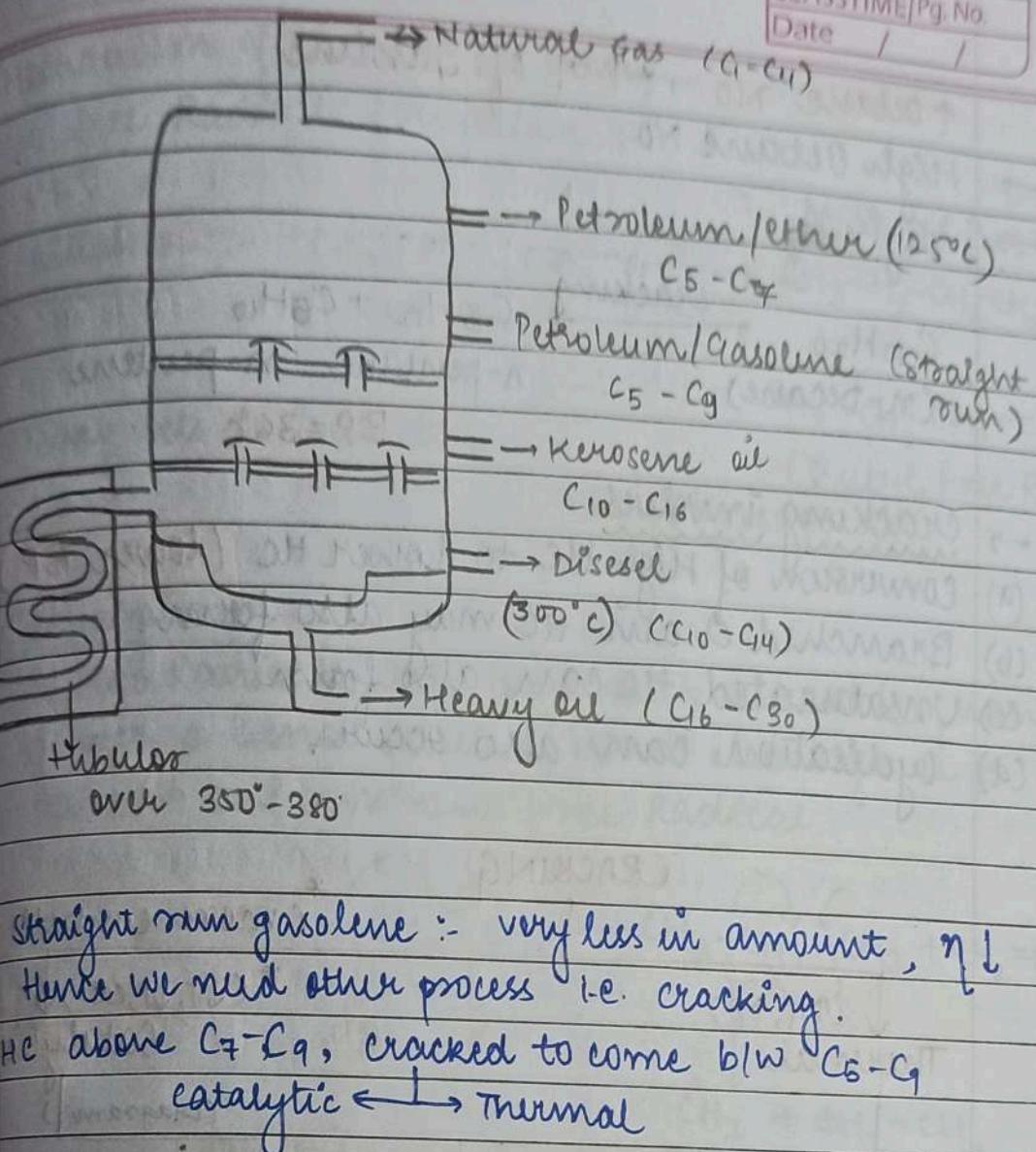
→ fractional distillation :-

Diff types of HC are removed using Boiling points
of diff HC.

Distillation \rightarrow condensation + vaporisation

Drawbacks :-

only for compounds with large diff b/w BP.



straight run gasoline :- very less in amount, $\eta \downarrow$
Hence we need other process i.e. cracking.

HC above C₇-C₉, cracked to come b/w C₅-C₉
catalytic \longleftrightarrow thermal

Date :- 23 Dec 2022

CRACKING OF COKE

Petrol \rightarrow Motor fuel / Gasoline

Only 20% from Refining of crude oil.

Not good quality of Gasoline

Straight Run Gasoline :- Gasoline directly from Refining

To fulfil Req :- Use cracking

cracking of High carbon H.C (>9C), we get
lower H.C known as Gasoline

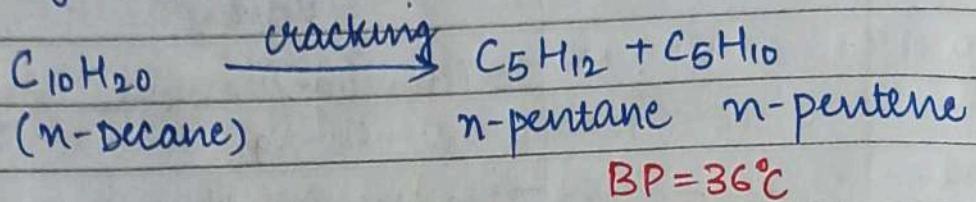
→ Controlled method

Catalytic Method \longrightarrow Thermal Method

\uparrow Octane No \rightarrow $\uparrow \gamma$ of Gasoline

\rightarrow High Octane No.

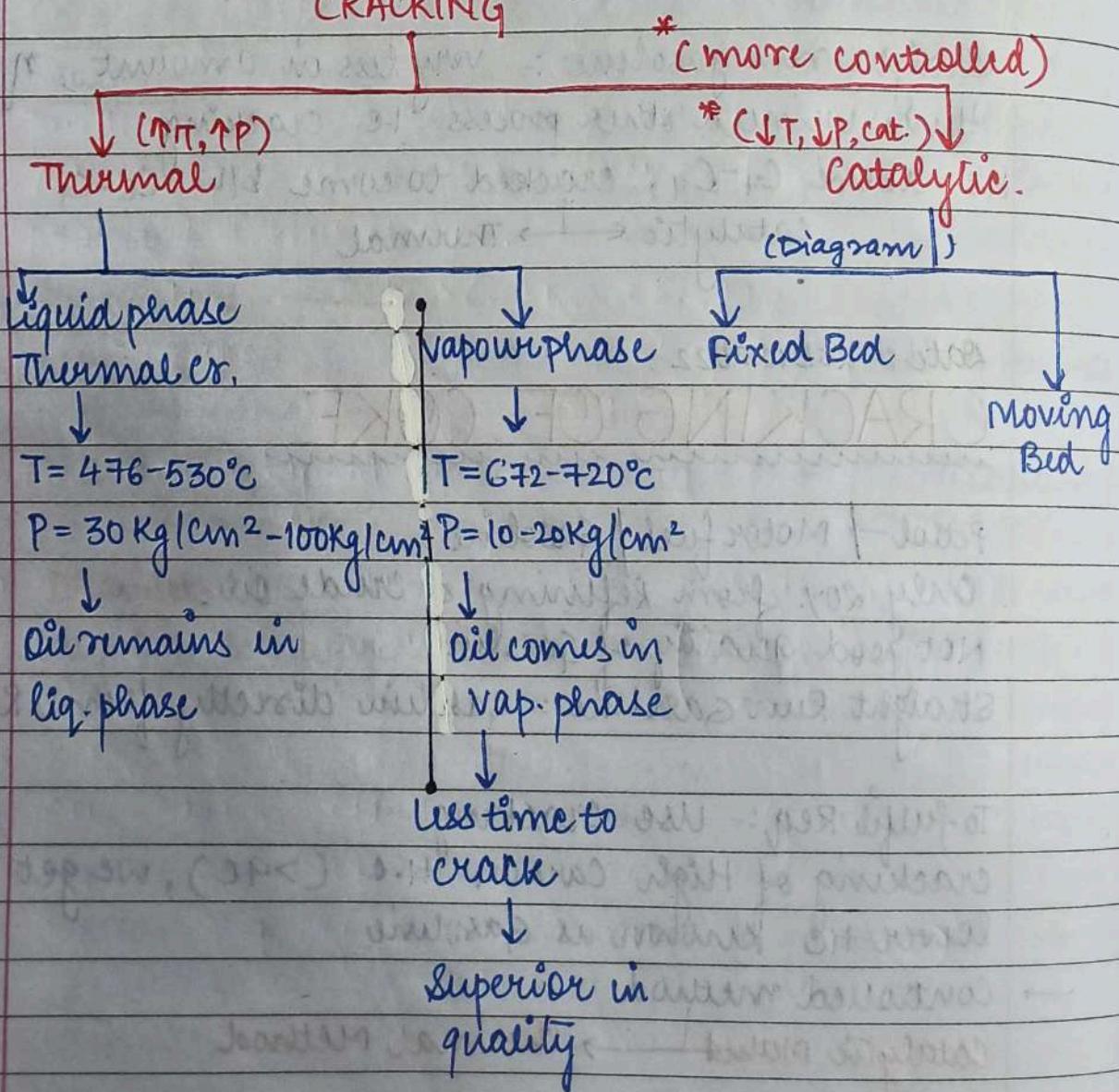
\rightarrow High γ



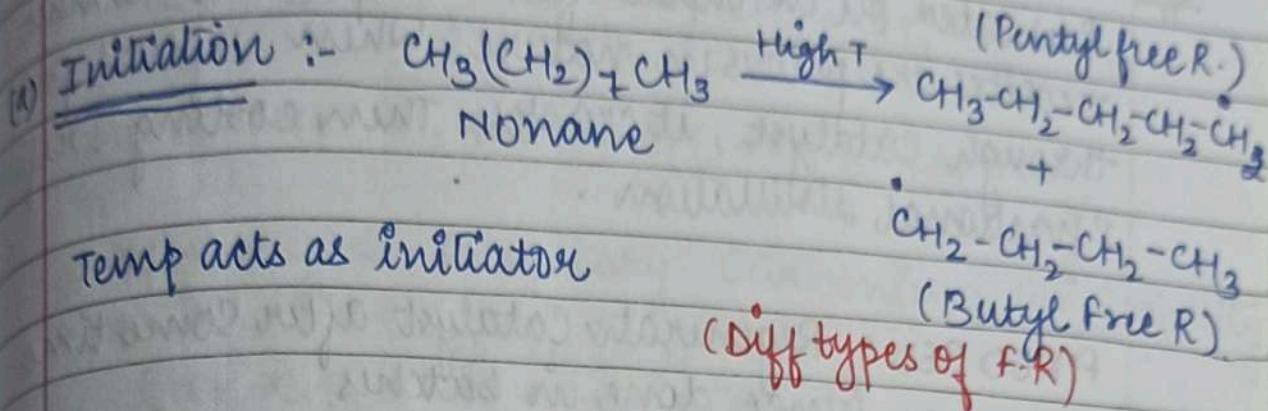
\rightarrow cracking involves

- (a) Conversion of High HC to Lower HC (lower BP)
- (b) Branched chain HC may also form.
- (c) Unsaturated HC can also form.
- (d) Cyclisation can also occur.

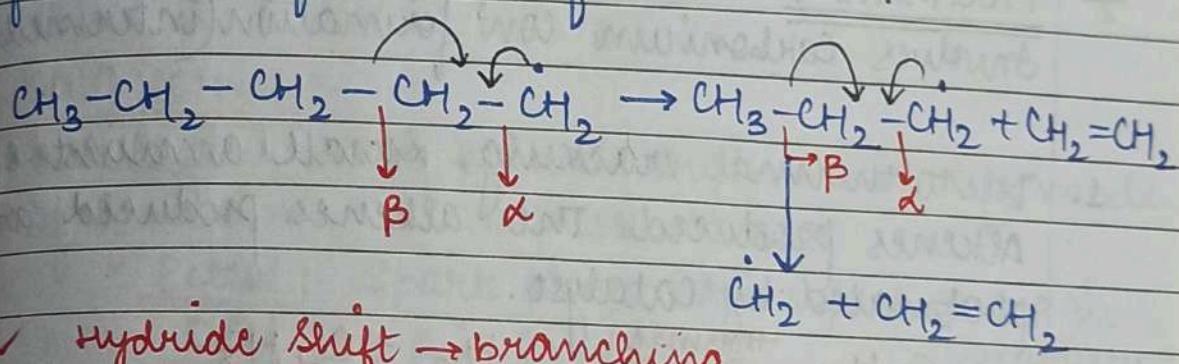
CRACKING



Mechanism of Thermal cracking
By free Radical formation :-

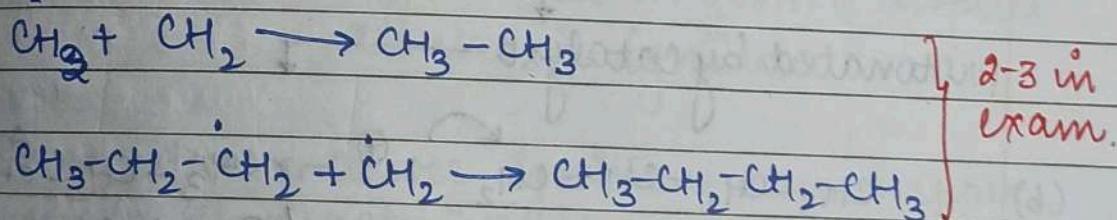


(b) Propagation :-
As free Radicals are thermally unstable, hence undergoes bond fission / bond cleavage at β -position to form new free Radical.



✓ hydride shift \rightarrow branching

(c) Termination :- Coupling

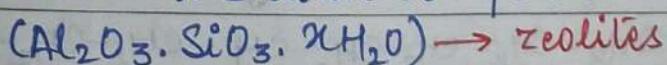


CATALYTIC CRACKING :-

This process occurs in presence of catalyst & comparatively at much lower temp & pressure.

Catalyst used :- Mix of Si & Alumina

i.e. hydrated Alumino Silicate compound



$$x = 2-6$$

Catalyst → donate proton

PROCESS:-

PROCESS:- Preluated oil in vapour form is fed in ^{tubular} chamber. zeolites are porous in nature. When vapours pass through catalyst, it cracks. Then cooling, refining & fractional distillation.

FIXED BED :- Regenerate Catalyst after some time hence done in batches.

Diagram
from :
Book

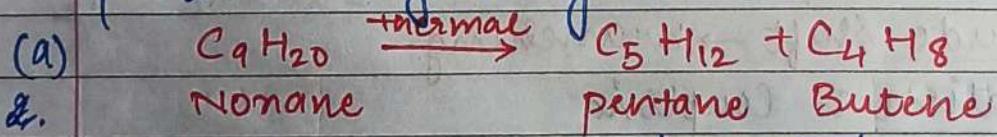
MOVING BED:- Regenerate Catalyst along with process
(faster)

Date:- 27 DEC, 2022.

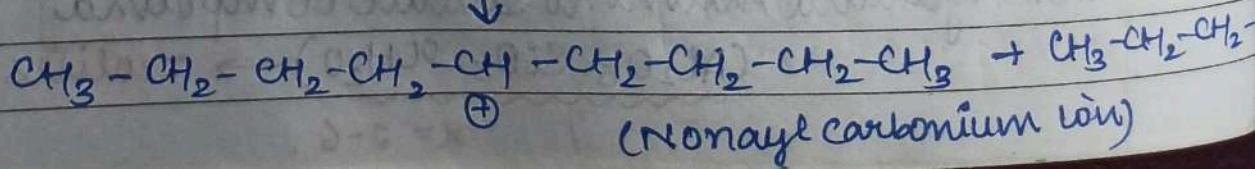
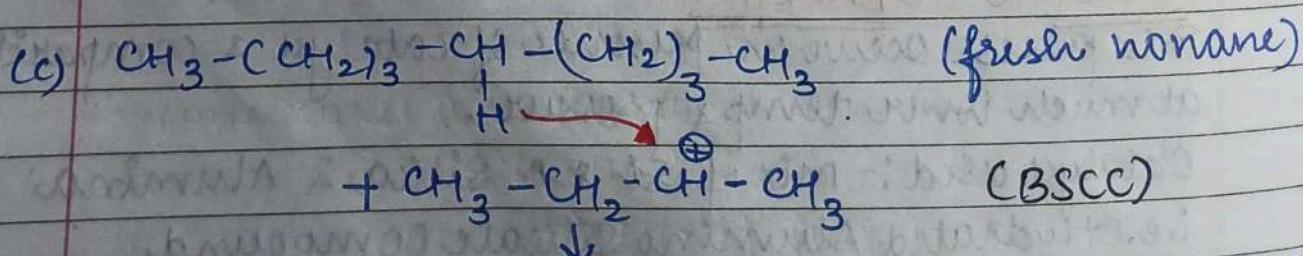
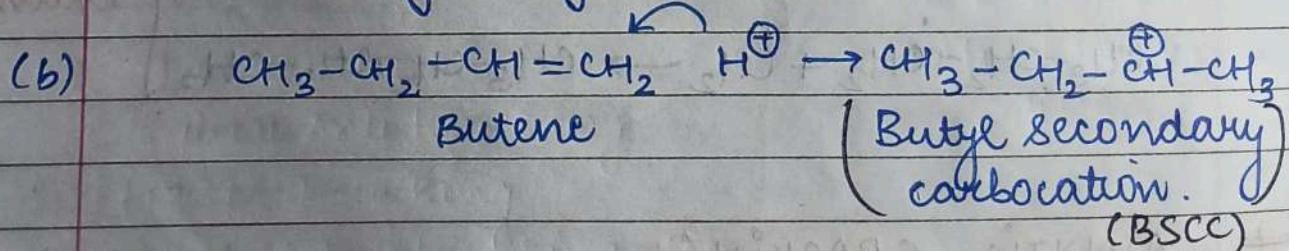
MECHANISM :- (Cracking of $\text{HC} > \text{C}_1\text{C}_2$)

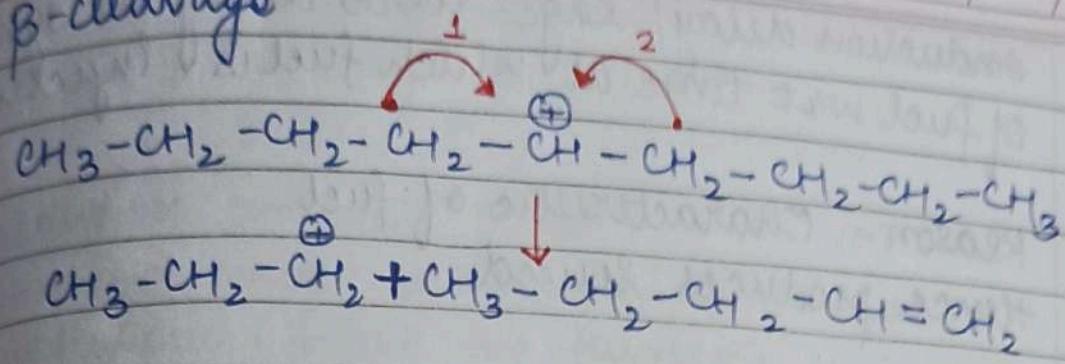
Involves carbonium ion formation (intermediate).

1. Due to thermal cracking, small amount of Alkenes produced. The alkenes produced are then protonated by catalyst.

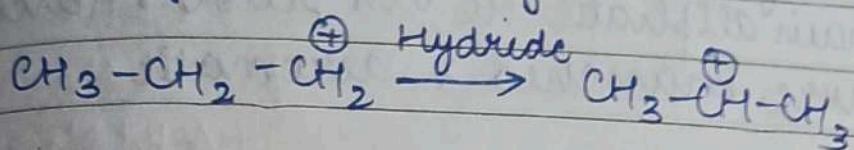


protonated by catalyst



β -cleavage

primary < secondary carbonium ion stability



Simultaneously, there is formation of diff types of carbonium ion as well as sep. of diff types of lower HC.

KNOCKING :-

4 stock in petrol & diesel engine but diff mode of ignition! (compression stock)

→ Petrol :- Spark plug (Air & fuel at $\downarrow P$) in

→ Diesel :- Air in cylinder compression stock

compress at $\uparrow P, \uparrow T$
inject fuel in form of droplets
results in ignition.

→ Petrol :- Pre mature ignition can happen.

(due to characteristic of fuel)

Ignition of fuel (Temp) $<$ Ign. of compression temp.

Hence produces sound → Disturbs movement of piston & cylinder. (sound like hammer on metal)

→ Diesel :- Delay ignition (inject fuel in compressed air/fuel)

Induction delay/ lag:- time delay in ignition of fuel wrt time at which fuel is injected.

Reason:- Characteristic of fuel.

Hence produces sound.

→ Petrol :- Eg where pre-ignition can happen:-
st-chain aliphatic HC in petrol. Hence should be more branched & aromatic

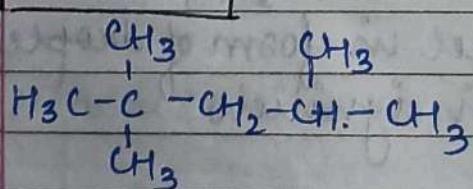
→ Diesel :- Where Aromatic & branched are more hence st-chain aliphatic HC is req.

→ Knocking :- The sound produced is knocking.

→ To measure ~~knock~~ knocking, we introduced,
Petrol :- Octane no.

Diesel :- Cetane no.

Octane



Iso-Octane

Highest Anti Knocking

Least Knocking

Value of Anti Knocking = 100

n-Heptane

Knocks very badly
(pre ignition)

Value assigned = 0

(anti-knocking value)

Octane no is a scale to measure knocking.
(No unit)

If Octane no = 70 \Rightarrow mix of fuel of 70% iso-octane & 30% n-heptane.

CETANE NO.

(Book)

octane NO benzene = 106

benzene not desirable in fuel due to pollution. (\downarrow B.P \rightarrow fumes)

ANTI-KNOCKING AGENTS :-

alcohol, Tetra- ethyl-lead (TBL) $Pb(C_2H_5)_4$

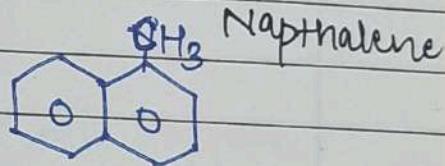
(soy.) \downarrow Costly, \downarrow Pollut, \downarrow used
to improve anti knocking value.

Cetane NO :-

Cetane

$CH_3-(CH_2)_{14}-CH_3$

n-hexadecane



least knocking

Anti-knocking value
= 100

α -Methyl Naphthalene

knocking highest
Anti Knocking value
= 0

Cetane no is scale to measure knocking in diesels.

Date :- 29 Dec, 2022.

LIQUID FUELS.

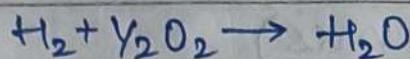
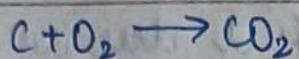
Advantages.

- Easy storage
- \uparrow C.V than solid fuels.

Producer Gas	4000 kcal/m ³	$\text{CO} = 22\text{-}30\%$, $\text{H}_2 = 8\text{-}12\%$, $\text{N}_2 = 5\%$
Water Gas	2800 kcal/m ³	$\text{H}_2 = 51\%$, $\text{CO} = 41\%$, $\text{N}_2 = 4\%$ Date / CO ₂ = 4%

LNG (liquified Natural Gas)
supercooled Natural Gas ↓ than 260°F.

Combustion Numericals



Oxygen 21% by vol

23% by wt.

78% vol N₂

77% wt N₂

Gaseous Fuels

Natural Gas	calorific value 12000 - 14000 Kcal/m ³	composition $\text{CH}_4 = 70\text{-}90\%$ $\text{C}_2\text{H}_6 = 5\text{-}10\%$ $\text{H}_2 = 3\%$ $\text{CO} + \text{CO}_2 = \text{rest}$
CNG	50,000 KJ/kg 12500 Kcal/kg	

LPG 27800 Kcal/m³

Coal Gas 4900 Kcal/m³ H₂ = 40%

CH₄ = 32%

CO = 7%

C₂H₄ = 3%, N₂ = 4%,

C₂H₆ = 2%

Air Gas

4500 - 5400 kcal/
m³

H₂ = 50-55%

CH₄ = 25-30%

CO = 10-12%

PHASE RULE

$$F = C - P + 2$$

J. W. Gibbs

for 2 phase in heterogeneous sys in equilibrium.

If sys depends on,

Temp, Pressure, Composition, ^{volume} & not on Surface Tension,
magnetic forces, etc.

F = degree of freedom.

C = no. of components

P = no. of phases.

Predicts necessary condns like T , P , etc.

Homogeneous :- Single phase

Heterogeneous :- Diff phases.

* PHASE :- A homogeneous & physically distinct part of a sys having definite boundary surfaces & is mechanically separable from other parts of the system.

e.g. oil + water \rightarrow separate phases \rightarrow phase \rightarrow immiscible

* Phase is homogeneous ^{part} of heterogeneous sys.

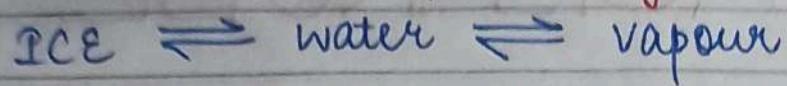
* Combination of gases is always 1 phase.

* Solids of diff compositions represents phase.

Sugar + Salt \rightarrow immiscible \rightarrow phase exist.
except alloys.

water system in equilibrium

One component system



only water \rightarrow 1 phase ; $P=1$

water + vapour in eqm \rightarrow 2 phases ; $P=2$

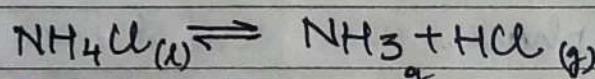
water + Ice in eqm \rightarrow 2 phases ; $P=2$

water + Ice + Vapour in eqm \rightarrow 3 phases ; $P=3$

#

Component:-

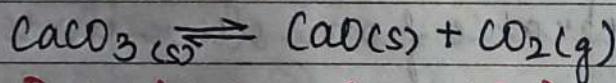
The ~~smallest~~ no. of independently variable constituents in terms of which the composition of each phase of heterogeneous sys can be expressed directly or in form of chemical eqn.



$P=2$ (NH_4Cl & ($\text{NH}_3 + \text{HCl}$))

$C=1$ (NH_4Cl)

$$F = C - P + 2 = 1 - 2 + 2 = 1$$



$P=3$ (CaCO_3 , CaO , CO_2)

$C=2$ (any 2 combination)

$$F = C - P + 2 = 2 - 3 + 2 = 1$$

C can never be zero.

Degree of Freedom:-

It is defined as min no. of independently variable factors such as T, P, Composition which must be specified in order to define system completely.

$F=0 \Rightarrow$ non variant sys
 $F=1 \Rightarrow$ univariant sys
 $F=2 \Rightarrow$ Bivariant sys

$F=3 \Rightarrow$ Trivariant sys.
 $(F=0, 1, 2, 3, P)$

Ans. Date / / Pg. No. / /

$$PV = RT$$

P, V, T are conserved variables
If we fix P, T, V is automatically fixed
hence $F=2$

composition / concentration

If P, T, C is fixed, V is automatically fixed

$$F=3$$

Water + vapour eqm :- $T=100^\circ\text{C}$, $P=1\text{ atm}$, specify mass

Water + vapour not in eqm :- Specify both T & P

Ice + water eqm :- Specify either T or P

Ice + water + vapour eqm :- Fixed values in nature of T, P, C , universal truth, Only $F=0$

DERIVATION OF PHASE RULE :-

consider a heterogeneous sys having 3×3 phases \Rightarrow C components. Acc. to definition, F_{sys} is min no. of independent variables which must be fixed arbitrarily to define system completely.

① - $F = \text{Total no. of variables} - \text{No. of Relationship b/w them at eqm}$

b/c every relation diminishes one of the factor

Total no. of variables = P, T, C

T \rightarrow 1 value only for a sys

P \rightarrow 1 value only for a sys.

C

Concn or composition variable :- No. of concn

variable for each phase = $C-1$ (component - 1)

no. of composition variable for P phase is
 $P(\text{component}-1) = P(C-1)$

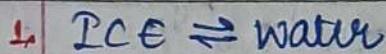
② ← Total variables = $P(C-1)(+2)$ → Pressure & temp.

Total Relationship = no. of reln at eqm for heterogeneous system



$$P=3$$

Relations



$\text{Ice} \rightleftharpoons \text{vapour} \rightarrow$ no need as can be deduced from 1 & 2

For heterogeneous sys with P phases, 1 component, no. of reln = $P-1$

③ ← No. of relationship for Component = $C(P-1)$

Put ② & ③ in 1.

$$F = C - P + 2$$

Application for 1 component system.

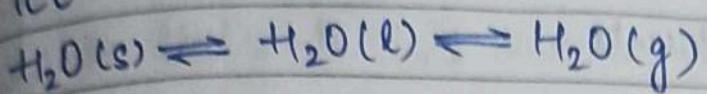
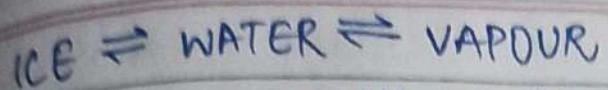
(1) H₂O system

$C=1$, no. of phases may be diff

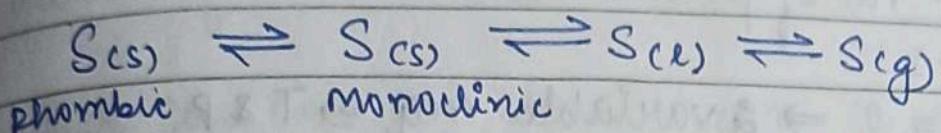
$$C=1, P=1, F=2$$

$$C=1, P=2, F=1$$

$$C=1, P=3, F=0$$



In case of Sulphur

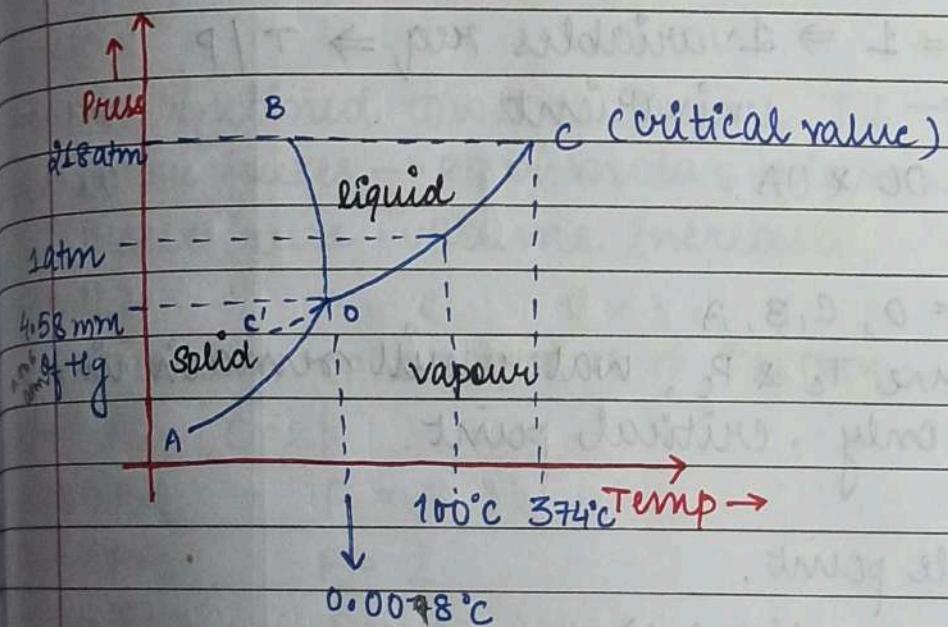


But can have only 3 at P at one time.

Highest F = 2 \Rightarrow Only 2 variables req to explain
1 component sys $\Rightarrow T, P$

2nd pd.

PHASE DIAGRAMS :-



OB \rightarrow curve b/w solid & liq \rightarrow Freezing curve /
 $\text{ICE} \rightleftharpoons \text{WATER}$ Melting curve.

OC \rightarrow curve b/w liq & gas \rightarrow vapourisation curve/
 $\text{WATER} \rightleftharpoons \text{VAPOUR}$ Condensation curve.

OA \rightarrow curve b/w solid & vapour \rightarrow sublimation curve
 $\text{ICE} \rightleftharpoons \text{VAPOUR}$.

Explanation
Curves, Area, Points

$\Rightarrow \underline{\text{Area}} = \text{OBC}, \text{OAB}, \text{OAC}$

$\text{OBC} :- \text{no. of phases} = 2 \neq 1$

$$C = 1$$

$F = 2 \Rightarrow 2 \text{ variables req} \rightarrow T \& P$

Bivariant.

Same with OAB & OAC.

$\Rightarrow \underline{\text{Curves}} = \text{OB}, \text{OC}, \text{OA}$

$\text{OB} :- \text{ICE} \rightleftharpoons \text{Liquid water}$

$$P = 2$$

$$C = 1$$

$F = 1 \Rightarrow 1 \text{ variable req} \rightarrow T / P$

univariant

likly for OC & OA.

$\Rightarrow \underline{\text{Points}} = O, C, B, A$

$C = \text{above } T_c \& P_c, \text{ water will remain in vapour}$
 $\text{phase only, critical point.}$

O = Triple point.

(for $C=1$)

* **Triple point** :- Point at which one component
 Sys exist in 3 phases.

ICE \rightleftharpoons water \rightleftharpoons vapours

$P=3, C=1, F=0 \Rightarrow \text{no specification of}$
 any value of T, P.

"OC' line" :- meta-stable curve b/w 2 forms meta-stable state. At this curve, water exist in 2 phases ICE \rightleftharpoons Supercooled water.

not a stable state. \rightarrow meta (false) state happen for short moment.

Water can exist in liq in $-ve^{\circ}C$ (upto till temp) But when water is pure (100%) (no foreign metals) only then it is seen.

Supercooled water is able to flow in pipes & has industrial use.

Only possible in water.

OB is inclined towards P axis, $T \downarrow \rightarrow P \uparrow$
water freezes $\rightarrow P \uparrow$ b/c molar volume will inc.
Water freeze, volume increase.

APPLICATION OF 2 COMPONENT SYSTEM :-

$$C = 2$$

$$P = 1 \quad F = 3$$

$$P = 2 \quad F = 2$$

$$P = 3 \quad F = 1$$

$$P = 4, \quad F = 0$$

Max phases = 4, practically max 3 possible.

$F = 3$ (max) = T, P, composition



3D diagram.

There are certain $C = 2$ sys which can be expressed in 2 variables. Eg:- (solid - solid / solid - liq) sys

b/c Pressure is Insignificance } condensed system
 But Phase rule changes, } system. → lead silver
Zn-Mg sys

$$F = C - P + L$$

condensed phase Rule (Defn)

Eg:- Sol-lig \rightarrow Na + SO₄ + water sys.

SOLID-SOLID SYSTEM :-

(1) Pb-Ag System.

Two component condensed system

Eg:- Pb-Ag

(a) Easily melting

(b) IC sys

(c) lowers each other's MP or F.P. \rightarrow eutectic components.

(d) cannot react chemically \times new compound

↓
eutectic sys

↓
sys having congruent MP

Zn-Mg

sharp melting point

IC sys

↓
lowers each other MP or FP.

New compound can be formed at some composition

↓
sys having incongruent MP

NaSO₄ + water

NaK system

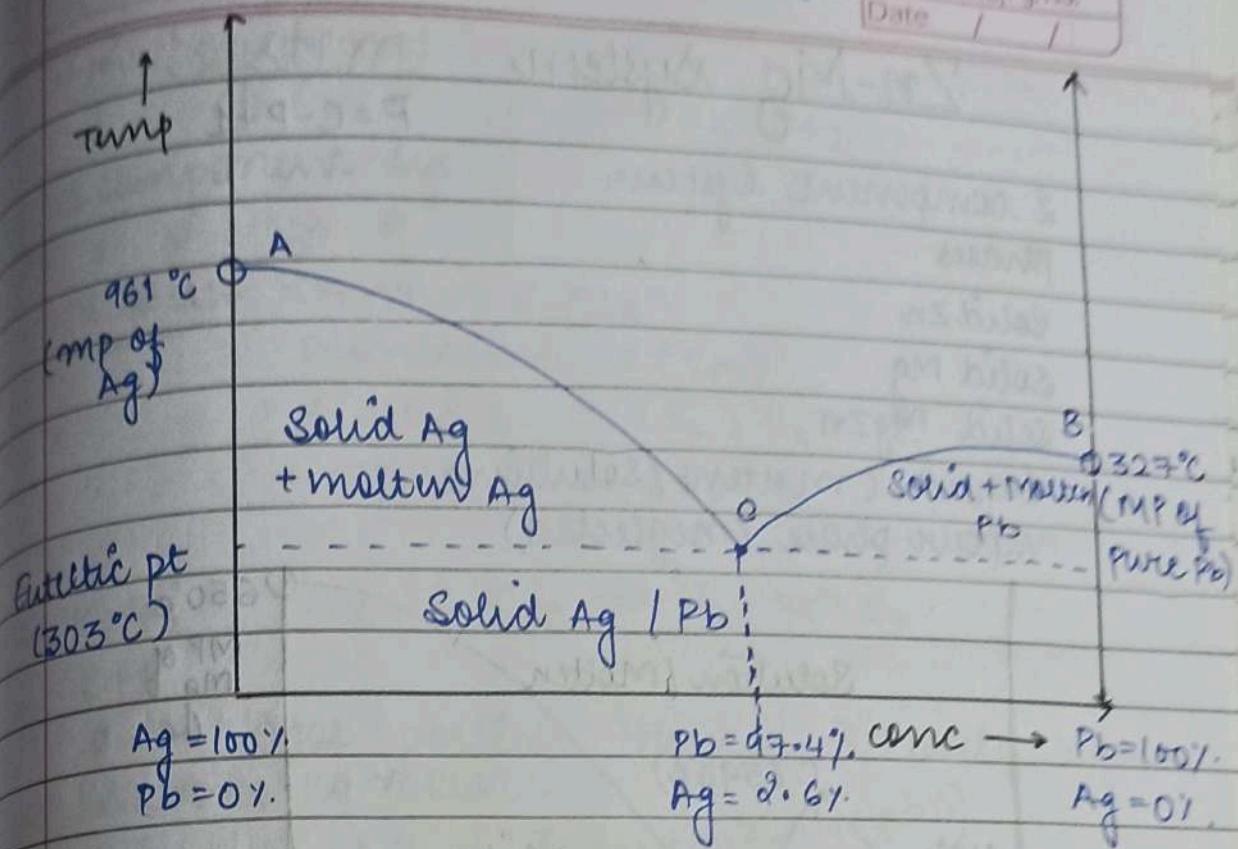
not sharp melting pt.

IC sys

New compound with not sharp MP.

Point = 0
 Line = 1
 Area = 2

CLASSTIME Pg. No.
 Date / / /



F_A

$$C=1, P=2 \text{ (solid + liq)}$$

$$F = C - P + 1 = 1 - 2 + 1 = 0$$

↓ MP when Ag is mixed with Pb.

at particular composition, MP is lowest → eutectic mixture → T = (easily melt) 303 °C

Application

- Low melting allows (fuse)
- fire systems.
- Desilverisation of argenti-ferrous lead (Patterson's process)
(separation of Pb & Ag)

Zn-Mg System

$$F = C - P + 1$$

2 component system.

Phases

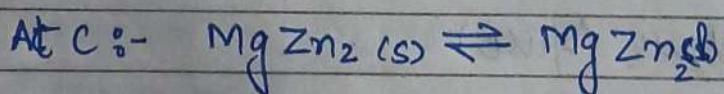
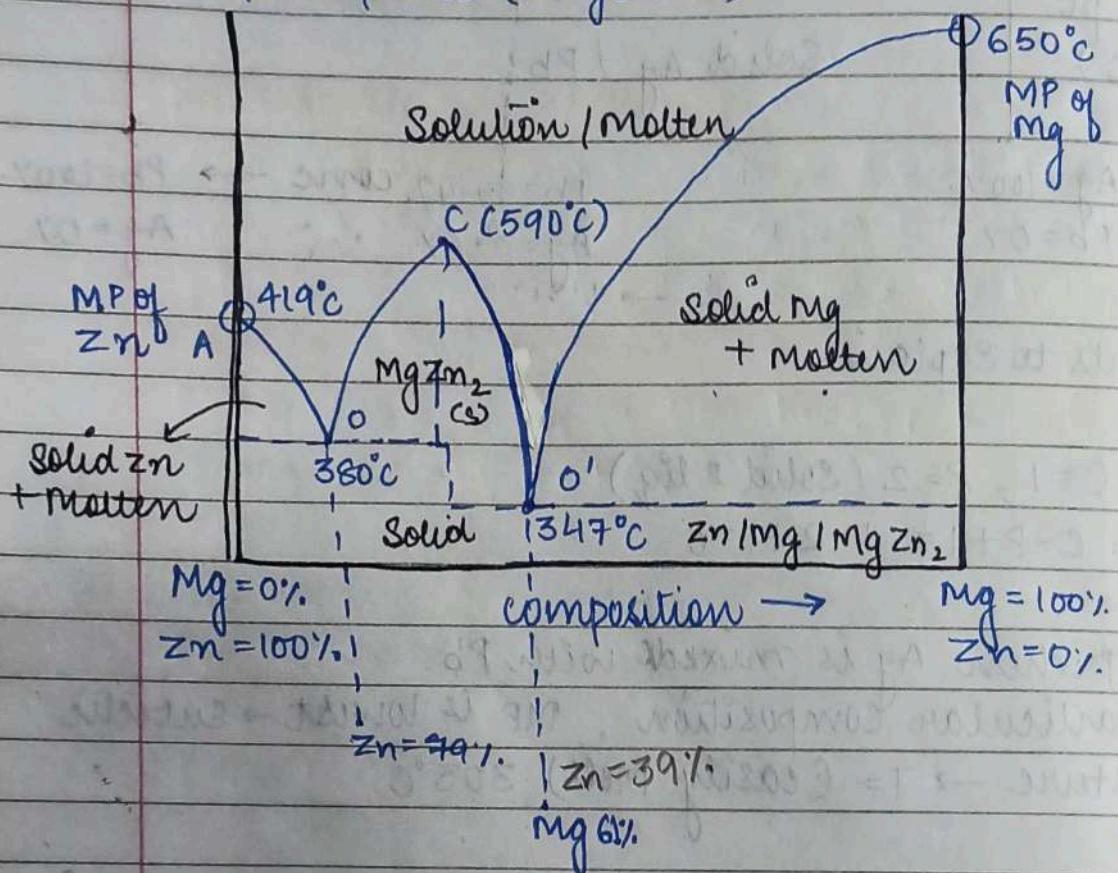
Solid Zn

Solid Mg

Solid $MgZn_2$

Liquid (Molten / Solution)

Vapour phase (neglected)



S-System

1 component sys

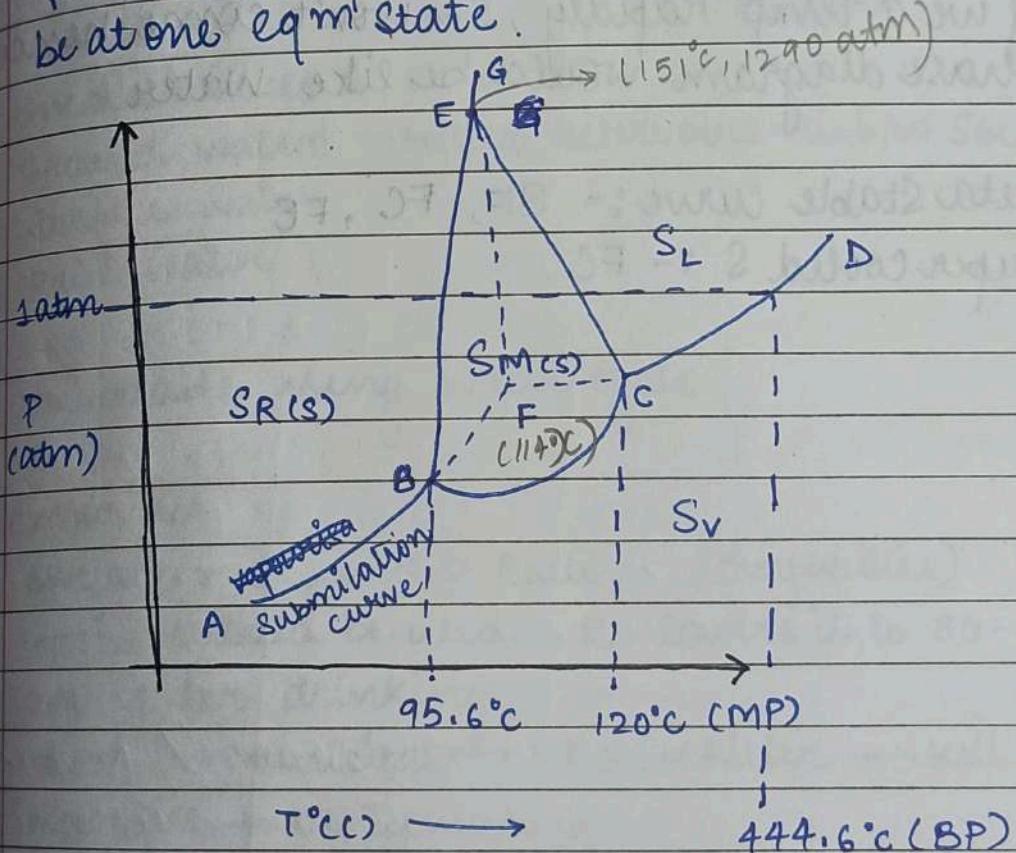
$$F = C - P + 2$$

- phases:-
- Rhomic S (SR)
 - Monoclinic S (Sm)
 - Liquid S (SL)
 - Vapour S (SV)

$$P=4, \quad SR \rightleftharpoons Sm \rightleftharpoons SL \rightleftharpoons SV$$

$$C=1$$

$F = -1$ not possible. Hence 4 would never be at one eqm state.



AB = sublimation Curve $SR \rightleftharpoons SV$

BC = sublimation Curve $Sm \rightleftharpoons SV$

BE = $SR \rightleftharpoons Sm$; Transition curve

CE = Melting curve ; $Sm \rightleftharpoons SL$

CD = Vapourisation curve ; $SL \rightleftharpoons SV$

GE = Melting curve $SR \rightleftharpoons SL$

Area	curve	Point
Phase = 1	Phase = 2	Phase = 3
C = 1	C = L	C = L
F = 2	F = 1	F = 0

3 triple point (B, C, E)

B :- $S_R \rightleftharpoons S_m \rightleftharpoons S_v$

Meta Stable :-

Transition from $S_R \rightarrow S_m$ is slow process.

If we \uparrow temp rapidly, S_m won't come hence phase diagram would be like water

Meta Stable curve :- BF, FC, FE

super cooled S :- FC.

: OVERVIEW :-

- surface, underground, Rain (sources)

- Impurities in chemical pov.

- Hardness (Numerical)

- Alkalinity ("")

- Boiler & corrosion

- Treatment

Water and Treatment 3

unit:-

T.1: Sources of Water

3 main sources

(a) Ground water → water reservoirs in b/w soil

(b) Surface water

(c) Rain water

→ convertible using water cycle.

T.2: Impurities

surface > ground > Rain (Impurities)

→ 100 TDS should be used, RO lowers it to 30-40 TDS, not fit for drinking.

→ 100 TDS → Municipal → X RO ✓ Filter → kill biological impurities → UV Technology

→ ISO Standard 10500 series → TDS upto 500 ppm is fit, rarely 1000 ppm.

→ 200-500 fit for drinking regularly.

→ Surface water :- have all types of impurities

↳ flowing → still water

Type of impurities

(a) Dissolved salts :- Inorganic & organic ;

(b) Gases :- Organic ;

(c) Acid :- Or & in or ; from industry & rain

(d) Suspended :- Inorganic ; surface (silica)

(e) Colloidal :- Org. ; (coloring act) oil, grease, pigment, from industry

(f) Biological :- biological impurity : in still water.

Effects :-

(a) Physical :-

(b) Chemical :-

(c) Biological :-

→ Rain Water :- Dissolved salts, Gases ✓, Acid ✓

Nitric & Sulphuric, suspended x, colloidal & Biological x

→ Ground water :- Dissolved salts x (soil acts as filter), Inorganic salts ✓, suspended ✓, Gases ↓, Acid ✓, colloidal & biological ↓.

Dissolved salt :-

- Ca, Mg, Fe, + heavy metal like I + hg, Ar, Pb, Bi, Cr (present generally in U.G water), very harmful
- Industrial waste is reason.
- hg: joint pain, heart.
- Arsenic: Bangladesh → towards India very & harmful.
- heavy metal X → safe for use.

⇒ chemical effects

- (a) Hardness
- (b) Alkalinity

Dissolved Gases :-

O₂, H₂, NH₃ in water (NH₃ from industries)

⇒ chemical effects

- (a) pH
- (b) Corrosion (O₂)

Fe corrosion → air (O₂) & water → O₂ in H₂O →
Corrosion ↑. CO₂ in water → corrosion ↑.

NH₃ → physical effect

Mineral Acid

Sulphuric, Nitric, HCl (HCl, H₂SO₄)
affects pH

CLASSTIME Pg. No.

soluble using methods → effect
 carbonate :- calcium carbonate
 ↓
 not soluble → no effect.

suspended :-

↳ soluble

→ Insoluble

→ suspended :- silica & clay

causes physical effect

→ colour (No colour in pure water) → colloidal

→ Taste

→ Odour → NH_3 or Gases & Biological

→ Turbidity

10 ppm (upto) Turbidity is acceptable.

Biological

Bacteria → biological effect.

Algae, fungi → physical

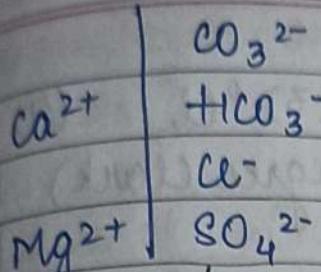
Effect (chemical)

HARDNESS	CORROSION	ALKALINITY
Dissolved salts of Mg (bicarbonate, carbonate, sulphate, chloride) & of Ca.	↓ Gases O_2 & CO_2 or due to acid	Due to salts of $\text{Na}, \text{K}, \text{Mg}$, etc, Anion OH^- , carbonate, bicarbonate
* Nitrate of Fe also produces Hardness * als of Mg & Ca.		

Date :- 19 Jan 2023

HARDNESS OF WATER

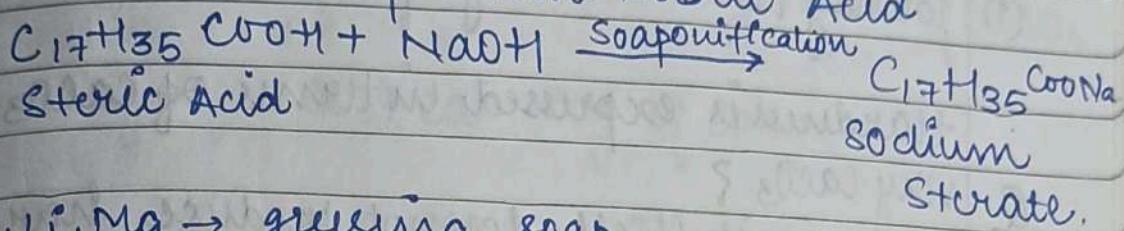
which cannot form lather with ~~some~~ soap
due to metallic ions (Ca & Mg ions in carbonate
bicarbonate, sulphate - Cl^-) present in water.



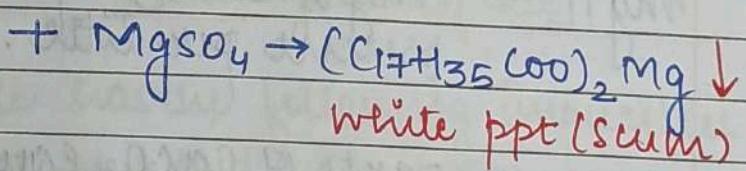
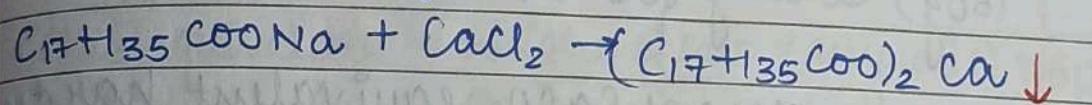
CaCO_3 is insoluble in water
It makes hardness only
when soluble in water.

Q why hard water cannot form lather

Li, Na, K Salt \rightarrow Soap with Steric Acid



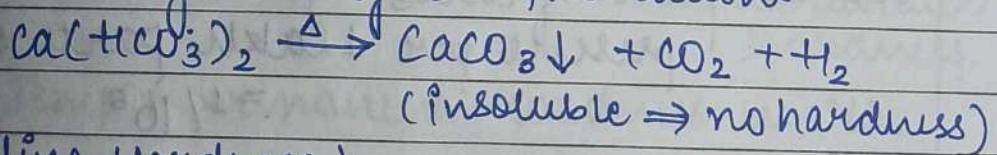
Na, Li, Mg \rightarrow greasing soap.
Na, K \rightarrow detergent.



Hardness is soap consuming capacity of water

Types of Hardness

(a) Temporary Hardness :- (Carbonate Hardness)
Carbonate & Bicarbonates of Ca & Mg. Can be removed by boiling or filtration



(Alkaline Hardness)

(b) Permanent Hardness :- (Non-Carbonate Hardness)
Sulphate & Chloride Salts of Ca & Mg. Lime soda process is used to remove hardness.

(Non-Alkaline Hardness)

unit of hardness

- (1) mg/L
- (2) ppm
- (3) °Cl
- (4) °Fr
(Degree Clark) Degree French

(1) 100 mg/L \rightarrow 100 mg of Salt in 1L.

Hardness is expressed in terms of CaCO_3 equivalent

Q Why CaCO_3 ?

- (i) because it itself does not produce hardness
- (ii) its molecular wt is round fig (100) & Eq. wt (50g) so easy for calculations

mg/L \rightarrow mg of CaCO_3 equivalent hardness present per litre.

ppm \rightarrow parts of CaCO_3 equivalent ions present in 10^6 litres $= \frac{1}{10^6}$

°U \rightarrow parts of CaCO_3 equivalent hardness present per 70,000 parts of water $= \frac{1}{70,000}$

°Fr \rightarrow parts of CaCO_3 equivalent hardness present per 1 lakh parts of water. $= \frac{1}{10^5}$

\Rightarrow unit conversion

$$\text{mg/L} \rightarrow \text{mg/kg} = \text{mg}/10^6 \text{mg} = \frac{1}{10^6}$$

$$\text{mg/L} = \text{ppm} = 0.07^\circ\text{U} = 0.1^\circ\text{Fr}$$

$x \text{ gm/L}$ of $\text{Ca}(\text{OH})_2 \rightarrow \text{Ca}(\text{HCO}_3)_2$. express in terms of CaCO_3 .

1 mole of $\text{Ca}(\text{HCO}_3)_2 = 1 \text{ mole of } \text{CaCO}_3$
~~162 g/mole~~

162 g/mole of $\text{Ca}(\text{HCO}_3)_2 = 100 \text{ g mole of } \text{CaCO}_3$

81 g of $(\text{HCO}_3)_2$, Ca = 50 g of CaCO_3

$x \text{ g of } \text{Ca}(\text{HCO}_3)_2 = \frac{50}{81} \times x \text{ g of } \text{CaCO}_3$

* CaCO_3 equivalent = Weight of salt (any unit) $\times 50$
Equivalent wt of salt

Q. A water sample has the following impurities

Impurity	Amount / wt (mg/L) (E)	CaCO_3
$\text{Mg}(\text{HCO}_3)_2$	83	73
$\text{Ca}(\text{HCO}_3)_2$	134	81
CaSO_4	124	68
MgCl_2	84	47.5
CaCl_2	94	55.5
Nace	50	— Does not produce — hardness

calc Temp & permanent hardness in °C.

$$\text{Mg} = 24$$

$$\text{H} = 1$$

$$\text{C} = 12$$

$$\text{O} = 16$$

$$\text{Ca} = 40$$

$$\text{S} = 32$$

$$\text{Mg}(\text{HCO}_3)_2 = 24 + (1 + 12 + 48) 2$$

$$= 24 + (71) \times 2 = 146 \text{ mg}$$

$$E(\text{Mg}(\text{HCO}_3)_2) = 73 \text{ mg}$$

$$E \text{ Ca}(\text{HCO}_3)_2 = 81 \text{ mg}$$

$$E \text{ CaSO}_4 = \frac{40 + 32 + 64}{2} = \frac{136}{2} = 68 \text{ mg}$$

$$E_{\text{mg/L}} = \frac{24+71}{2} = \frac{95}{2} = 47.5 \text{ mg}$$

$$E_{\text{calc}} = 55.5 \text{ mg}$$

Total hardness = 403.82 mg/L

Permanent hardness = 264.27 mg/L

Temporary hardness = 139.55 mg/L

In °C $\Rightarrow \times 0.07$

Date: - 20 Jan 2023

EDTA

Determination of hardness using
method

hardness of unknown water

Method :-

- Soap titration method (not accurate)

- EDTA, commercially used (accurate)

EDTA = titrant

COMPLEXOMETRIC TITRATION using Eriochrome

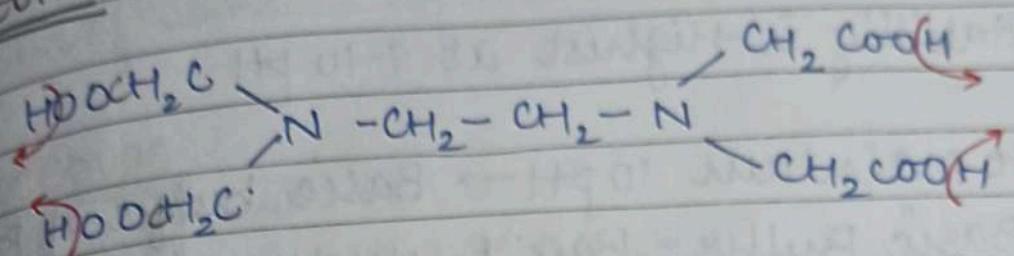
Black-T as Indicator & standard EDTA as
titrant

EDTA is complexing agent, form ligand with
metal ion. In hardness, Ca^{2+} & Mg^{2+} are metal
ion. Eriochrome Black-T is azo dye which
ionise at diff pH. EBT is weak ligand
but is complexing agent.

complex + EBT \rightarrow colour

Complex with EDTA \Rightarrow colourless

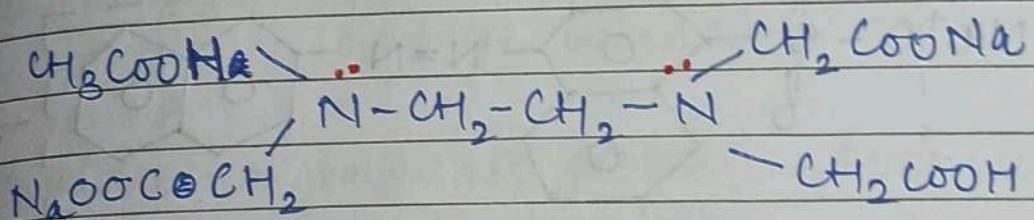
THEORY:- EDTA :- Ethylene diammine tetra acetic acid



zwitter ion is form after removal of H.

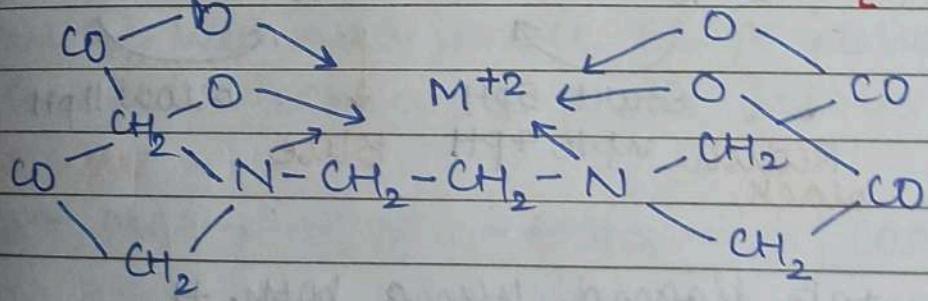
Representation :- H_4Y , H_3Y^- , H_2Y^{2-} , HY^{3-} , Y^{4-}
These are pH dependent.

H_4Y is slightly soluble \rightarrow used as titrant
& hence we take disodium (trans) salt.



Tetradentate or hexadentate ligand
(using LP of N)

Structure of EDTA with metal ion $[\text{M}^{+2} \leftarrow \text{EDTA}]$



M is metal
cage like structure \Rightarrow Stability $\uparrow \Rightarrow$ SFL.

→ Stable complex

1:1 complex (1 EDTA & 1 metal ion)

→ colourless at every pH.

Stability is highest at 9-10 pH

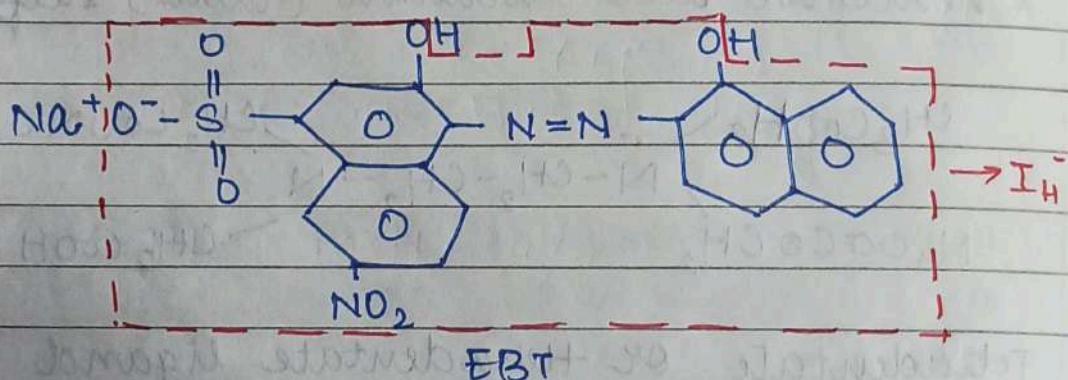
to maintain 10 pH → Basic buffer of pH 10

Basic Buffer = Base + counter salt

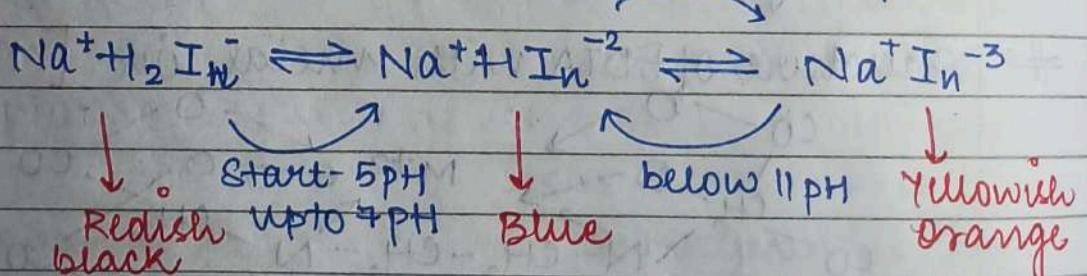
for 10 → 8 pH = Weak Base + counter salt

$\text{NH}_4\text{Cl} + \text{NH}_4\text{OH}$ is used here as buffer
in particular Ratio.

BEBT :- Eriochrome Black-T



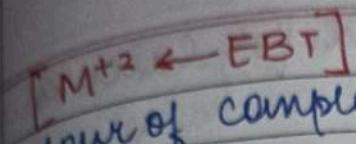
diff structure at diff pH



Bidentate ligand using both H.

but bcz of no symmetry weak ligand

- (i) Unstable at every pH
- (ii) 1:1
- (iii) coloured compound & ATB3



with metal ion
colour of complex with EBT at pH 10 is wine Red

PROCEDURE :-

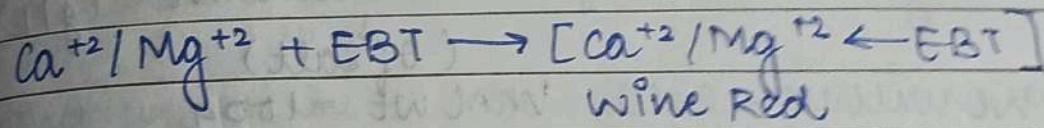
Standardization of EDTA

To determine Total hardness

To det temp & permanent hardness

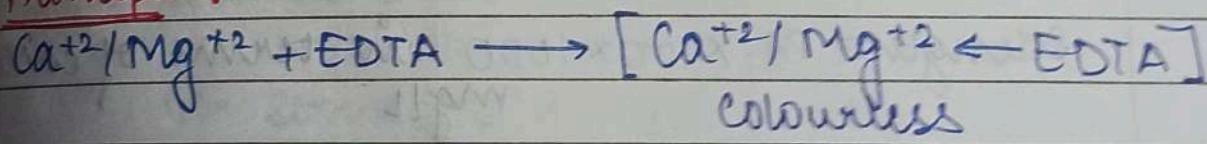
(i) pipet out known amt of hard water in conical flask. Add known buffer (10mL → 2mL buffer) & (20mL → 3mL buffer). Add EBT.

Principle :-



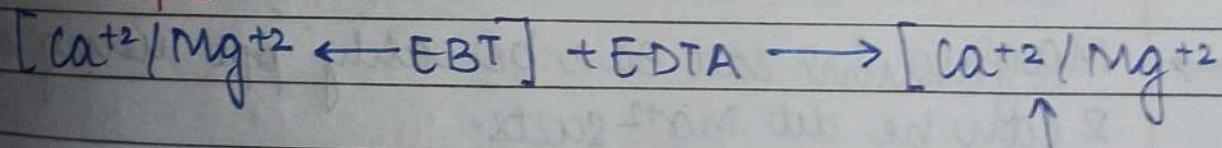
Add std EDTA ($n=2$) ($MW=397$). EDTA will form complex with free ions.

Principle :-



when we will add more EDTA, it will break wine Red complex to make stable compound.

Principle



now EBT is free & colour of EBT is blue at 10 pH

wine red → Blue

we will use vol of EDTA used for calculations

Calculations

Total hardness :- given
 Pipette \uparrow

$$M_1 V_1 = M_2 V_2 \rightarrow \text{concordant}$$

water = EDTA

M_1 = molarity of salts present in water
 (combined of Ca^{+2} & Mg^{+2})

Strength = Molarity \times Molecular wt (g/L)

(of salt)

we will use CaCO_3 mol.wt = 100 g

$$\text{g/L} \rightarrow \text{mg/L} \times 1000$$

$$\text{Strength} = M_1 \times 100 \times 1000 \text{ in terms of } \text{CaCO}_3$$

mg/L

Procedure

Temp hardness = Boil water

(3) For permanent hardness

Boiled water & same procedure

→ Magnesium salt can be easily ppt using base
 & can be det Mg^{+2} salts



But now for Ca^{+2} , we cannot use EBT

because of $\text{pH} > 12 \rightarrow$ no colour of EBT.
Indicator \rightarrow Calconic

$12.5 < \text{pH} \rightarrow$ pink in complex state
free state, $12.5 < \text{pH} \rightarrow$ purple blue.

(ii) Standardisation of EDTA :-

EDTA is not primary standard. we need to standardise it using titration.

Primary Standard :- whose normality is fixed with time.

generally not fixed bcz of impurities.

Standardising Base \rightarrow Acid is used & vice-versa

what we use here :- Standard hard water

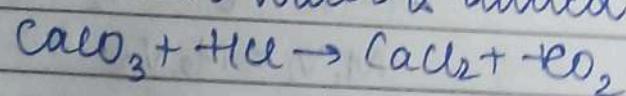
(std soln of CaCO_3 in distilled water)

in 1g/L or 1mg/mL unit.

Strength = Molarity \times mol. wt.

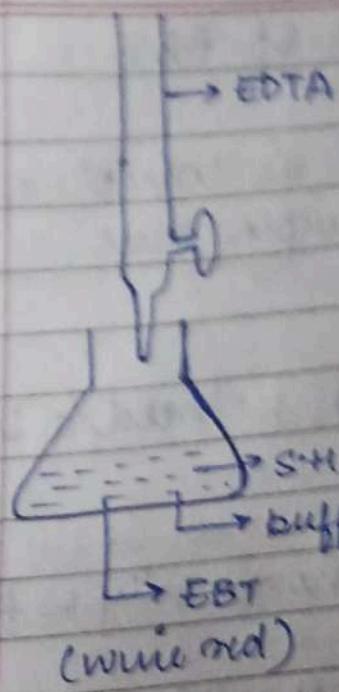
$$M = \frac{\text{Strength}}{\text{mol wt}} = \frac{1}{100} = M_1$$

But how to dissolve CaCO_3 in water. \rightarrow using the paste is formed & then water is added



Precaution

- (a) Shake water before pipette.



wini red \rightarrow blue

$$M_1 V_1 = M_2 V_2$$

$$S.H.W. = EDTA$$

M_1 from (1)
we need to find M_2 .

use M_2 in second part.

Q \downarrow 1 g of CaCO_3 was dissolved in dilute & the soln diluted to 1 L . 100 ml of this solution req 90 ml of EDTA solution. While 100 ml of sample water req 40 ml of EDTA. On the other hand 100 ml of sample water when titrated against EDTA consumed 20 ml of EDTA solution. Calculate total temporary & permanent hardness of water in terms of CaCO_3 in ppm or mg/L.

A1 Strength of S.H.W. = $1\text{ g/L} \Rightarrow M_1 = \frac{1}{100}$

$$V_1 = 100\text{ ml} \quad V_2 = 90\text{ ml}$$

$$M_1 V_1 = M_2 V_2$$

$$\frac{1}{100} \times 100 = M_2 \times 90 \Rightarrow M_2 = \frac{1}{90} \text{ M}$$

Now $V_{\text{water}} = 100\text{ ml}$, $V_{\text{EDTA}} = 40$, $M_{\text{EDTA}} = \frac{1}{10}$

$$M_w V_w = V_{\text{EDTA}} M_{\text{EDTA}}$$

$$M_w = \frac{40 \times \frac{1}{10}}{90} = \frac{4}{900} \text{ M}$$

$$\text{Strength} = \frac{4}{900} \times 100 \times 1000 = \frac{4000}{9} = 444.4 \text{ mg/L}$$

Total Hardness = 444.4 ppm

$$V_W = 100 \text{ mL}, V_{EDTA} = 20 \text{ mL}, M_{EDTA} = \frac{1}{90} \text{ M}$$

$$M_W = \frac{20 \times \frac{1}{90} \times \frac{1}{100}}{\frac{1}{100}} = \frac{2}{900}$$

$$\text{Strength (permanent)} = \frac{2}{900} \times 100 \times 1000 = \frac{2000}{9} = 222.2 \text{ mg/L}$$

$$\begin{aligned} \text{Temporary} &= \text{Total Hardness} - \text{Permanent} \\ &= 444.4 - 222.2 = 222.2 \text{ mg/L} \end{aligned}$$

Q2 100mL of sample water required 20mL of 0.01M of EDTA for titration using EBT as indicator.

After Boiling, 100mL of sample required 10mL of 0.005M EDTA. cal Permanent & Temp hardness of Water Sample.

$$\underline{\text{A2}} \quad V_W = 100, M_W = ?, V_E = 20, M_E = 0.01$$

$$M_W = \frac{20 \times \frac{1}{100} \times \frac{1}{100}}{\frac{1}{100}} = \frac{2}{1000} \text{ M}$$

$$\text{Strength} = \frac{2}{1000} \times 100 \times 1000 = 200 \text{ mg/L}$$

$$\text{Total Hardness} = 200 \text{ mg/L}$$

Now,

$$V_W = 100, M_W = ?, V_E = 10, M_E = 0.005 = \frac{5}{1000}$$

$$M_W = \frac{10 \times \frac{5}{1000} \times \frac{1}{100}}{\frac{1}{100}} = \frac{5}{10000}$$

$$\text{Strength} = \frac{5}{10000} \times 100 \times 1000 = 50 \text{ mg/L}$$

Permanent Hardness = 50 ppm
 Total Hardness = 200 ppm
 Temporary Hardness = 150 ppm.

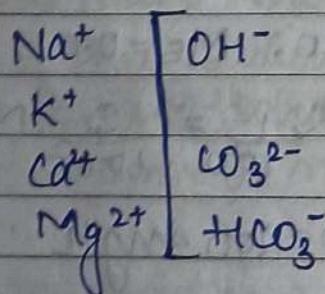
Date :- 24 Jan 2023.

ALKALINITY OF WATER

alkaline :- water soluble base
 cause alkalinity of water.

Amount of dissolved alkalinity in water
 or amount of acid that can be neutralised
 by water.

Reason :- OH^- , CO_3^{2-} , HCO_3^- of $\text{Na}, \text{K}, \text{Ca}, \text{Mg}$
 metal ions

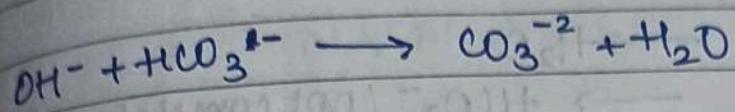


base, salt or ions of OH^- , CO_3^{2-} , HCO_3^- .

Possibility of presence of Alkalinity

- (i) Alone OH^-
- (ii) Alone CO_3^{2-}
- (iii) Alone HCO_3^-
- (iv) OH^- & CO_3^{2-}
- (v) CO_3^{2-} & HCO_3^-

other possibilities are not possible bcz



Determination of Alkalinity

units :- mg/L, ppm, CaCO_3 equivalent

known amt of water titrated against acid.
Acid-Base / Neutralisation Titration.

Indicator :- changes colour with pH.

- pipette out water & fill in it flask.
- Indicator :- 7-11.5 < Yellow of methyl orange
Acidic \rightarrow Red
(colour at every pH)
- burette :- std acid (H_2SO_4 , HCl)

Yellow \rightarrow Red end pt.

$$n_1 M_1 V_1 = M_2 V_2 n_2 \Rightarrow n_1 V_1 = N_2 V_2$$

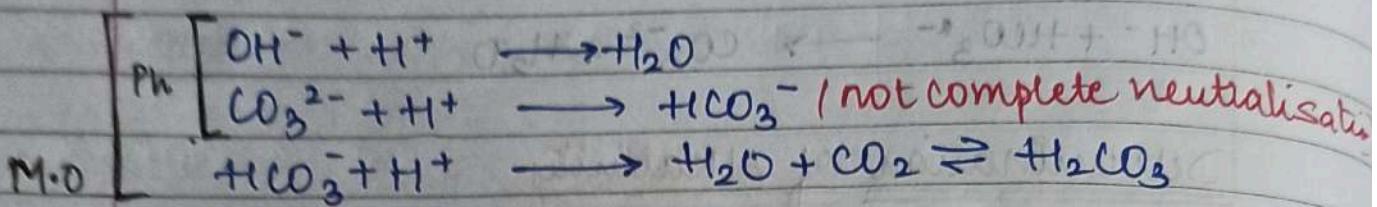
water = Acid water Acid

$$N_1 = \frac{N_2 V_2}{V_1}$$

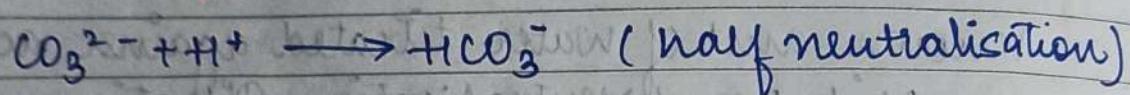
This N_1 is due to alkaly present in ~~bas~~ water
(combined for all ions)

$$\begin{aligned} \text{Strength} &= N_1 \times \text{eq wt g/L} \\ \text{Alkalinity} &= N_1 \times \frac{100}{2} \times 1000 \text{ mg/L} \\ &= N_1 \times 50 \times 1000 \text{ mg/L} \end{aligned}$$

Water + acid \rightarrow neutralisation reactions



Alkalinity due to particular ion



CO_3^{2-} needs double H^+ for complete neutralisation.

Working pH of phenolphthalein :- pH 8 - 9.5 pink

Hence phenolphthalein can detect

OH^- & half of CO_3^{2-} ion

HCO_3^- is ~~weak~~ base \rightarrow pH $>$ 8 Hence we use methyl orange for all three

Alkalinity using phenolphthalein indicator (P)

(P) = 11

Pink \rightarrow colourless

$$n_1 M_1 V_1 = n_2 M_2 V_2$$

$$N_1 V_1 = N_2 V_2$$

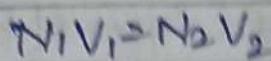
Water Acid

$$N_1 = ?$$

Strength = ?

Methyl orange Alkalinity of water (M)

(Total Alkalinity)

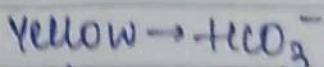


Water Acid

$N_1 = ?$ Strength?

$$V_2 \text{ MO} \geq V_2 \text{ ph.}$$

$M = P + \text{extra vol.}$



\downarrow
Red ($\times +\text{HCO}_3^-$)
neutral.

Cases

i) If $P=0$ \rightarrow only bicarbonate present or no alkalinity
 \rightarrow Only $+\text{HCO}_3^-$ present

Then alkalinity due to $+\text{HCO}_3^- = M$

ii) If $P=M$ \rightarrow only hydroxyl is present (or $M=0$)
 Then alkalinity due to hydroxyl $= P/M$

iii) $P = \frac{1}{2} M$ \rightarrow only CO_3^{2-}

Then alkalinity due to $\text{CO}_3^{2-} = M$

iv) If $P < V_2 M$ $\Rightarrow \text{CO}_3^{2-} \& +\text{HCO}_3^-$

Alkalinity due to $\text{CO}_3^{2-} = 2P$

$$+\text{HCO}_3^- = M - 2P$$

v) If $P > V_2 M$ $\Rightarrow \text{OH}^- \& \text{CO}_3^{2-}$

Alkalinity due to $\text{CO}_3^{2-} = 2(M-P)$

$$\text{OH}^- = M - 2(M-P) = 2P - M$$

Q1 100 mL require 20 mL N/50 H₂SO₄ for phenolphthalein end point and another 15 mL for complete neutralisation. Calculate type of hardness in ppm.

Ans True P = 20 mL and M = 70 mL

$$\frac{1}{2} M = 35 \text{ mL}$$



P < $\frac{1}{2} M \Rightarrow \text{CO}_3^{2-}$ and HCO_3^- are present in water.



$$N_1 V_1 = N_2 V_2$$



water Acid

$$100 N_1 = \frac{1}{50} \times 20$$

$$N_1 = \frac{1 \times 20}{50 \times 100 \times 50} = \frac{1}{250} \text{ N} \Rightarrow P$$

$$\text{Strength} = \frac{1}{250} \times \frac{100}{2} \times 1000 = 200 \text{ mg/L}$$

$$N_1 V_1 = N_2 V_2$$

water Acid

$$100 N_1 = \frac{1}{50} \times 35$$

$$N_1 = \frac{1}{50} \times \frac{70}{100} \times \frac{1}{2} = \frac{7}{500} \text{ N} \Rightarrow M$$

$$\text{Strength} = \frac{7}{500} \times \frac{100}{2} \times 1000 = \frac{1400}{2} \text{ mg/L}$$

$$\text{CO}_3^{2-} \rightarrow \Delta P = 400 \text{ ppm} \quad = \frac{700}{2} \text{ mg/L} = 350 \text{ ppm}$$

$$\text{HCO}_3^- \rightarrow 700 - 400 = 300 \text{ ppm}$$

$$M = 350 \text{ ppm} \quad P = 200 \text{ ppm}$$

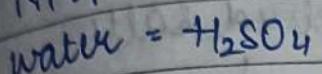
$$P > \frac{1}{2} M \Rightarrow \text{OH}^- + 2 \text{CO}_3^{2-}$$

$$[\text{CO}_3^{2-}] = 2(350 - 200) = 300 \text{ ppm}$$

$$[\text{OH}^-] = 400 - 350 = 50 \text{ ppm}$$

100mL of water sample req 30mL N/50 H₂SO₄ upto O₂
pH end point & 50mL for complete neutralisation
Type and extent of Alkalinity.

$$N_1 V_1 = N_2 V_2$$



$$100 \times N_1 = \frac{1}{50} \times 30.$$

$$N_1 = \frac{1}{50} \times 30 \times \frac{1}{100} = \frac{3}{500} \text{ N} = P$$

$$St = \frac{3}{500} \times \frac{100}{2} \times 1000 = \frac{3}{5} \times \frac{1000}{2} = \frac{600}{2} \text{ ppm}$$

- 300 ppm.

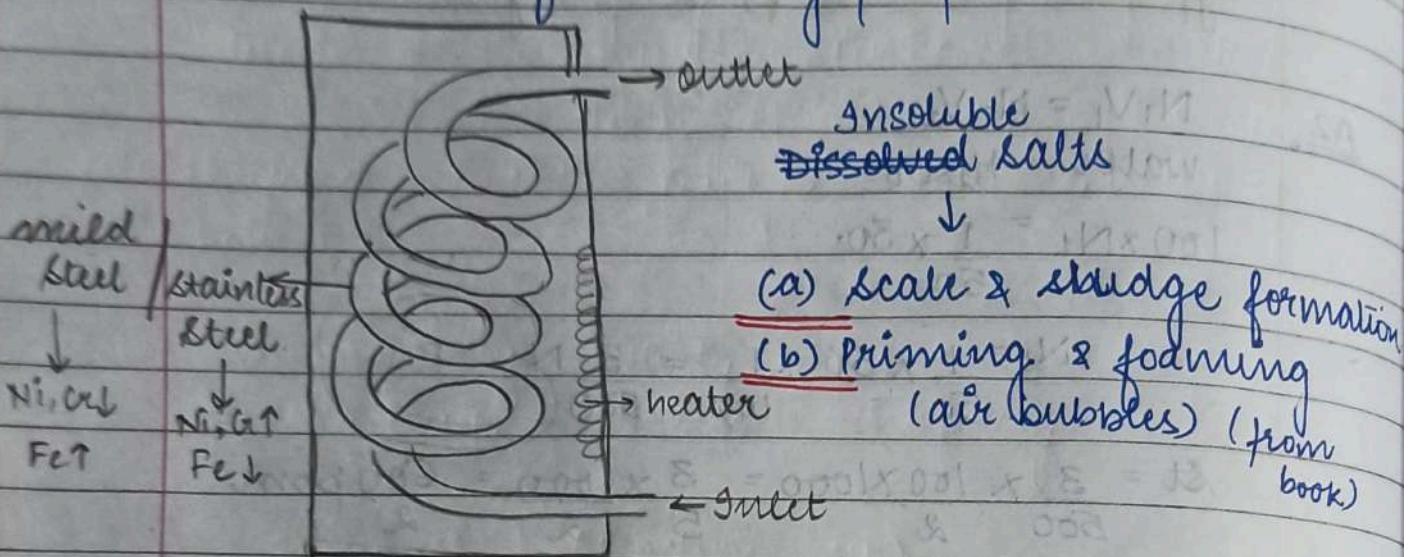
$$N_1 V_1 = N_2 V_2$$

$$100 \times N_1 = \frac{1}{50}$$

$$N_1 = \frac{1}{100} \text{ N} = M$$

PROBLEM IN BOILERS

boiler is used for heating purpose.

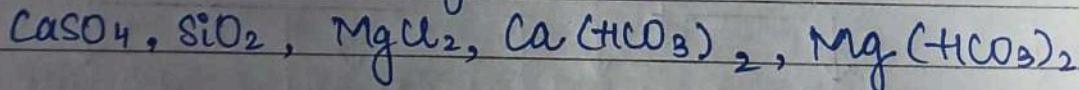


(a) Dissolved Acids → (c) Boiler corrosion
Dissolved Gases (O_2 & CO_2)

(d) Caustic embrittlement → strong base (alkali)
($NaOH$)

Scale & Sludge formation

Reason:- Dissolved salts beyond saturation level



- In water sample → dissolved form
- In boilers → water evaporates → % ↑ salt bcz solvent evaporates Solute same → saturation level
- Insoluble form ppt → Salt thrown out to inner walls of coils → lumps formation

Sludge

Sludge :- soft & slimy. colder Region, salt insoluble in cold water

Scale :- hard & lumpy, difficult to remove using chisel & hammer. hotter region

$\text{CaSO}_4 \rightarrow$ insoluble in
hot water

$\text{Si}^{\circ}\text{O}_2 \rightarrow$ react with Ca & Mg

CLASS TIME Pg No
Date _____
react with ca²⁺ ions
to form CaSiO_3 & MgSiO_3
(insoluble in
hot water)

by salts insoluble in hot water.

Scales - CaSO_4 & SiO_2
Sludge :- rest all.

problems

- (A) blocking efficiency ↓
(B) more energy (h_u that is req) for desired outlet temp
(C) thermal shocking → steam ↑ → pressure ↑↑ →
(D) boiler burst.

Prevention method

- (i) blow-down process
(high speed water from outlet \rightarrow Inlet)
 - (ii) brushing
 - (iii) chemical method for :- scale

External

(same as those of removing hardness of water)

Internal

(1) Sequestration is a process in which we convert an ion if prohibited to exhibit its original properties either by converting it to some other form or by forming a soluble complex with some other compounds.

sodium aluminate
 NaAlO_2

Date : - 31 Jan
CLASSTIME Pg. No.
Date / /

Sludge :- Adhere softly, colder region of boilers,

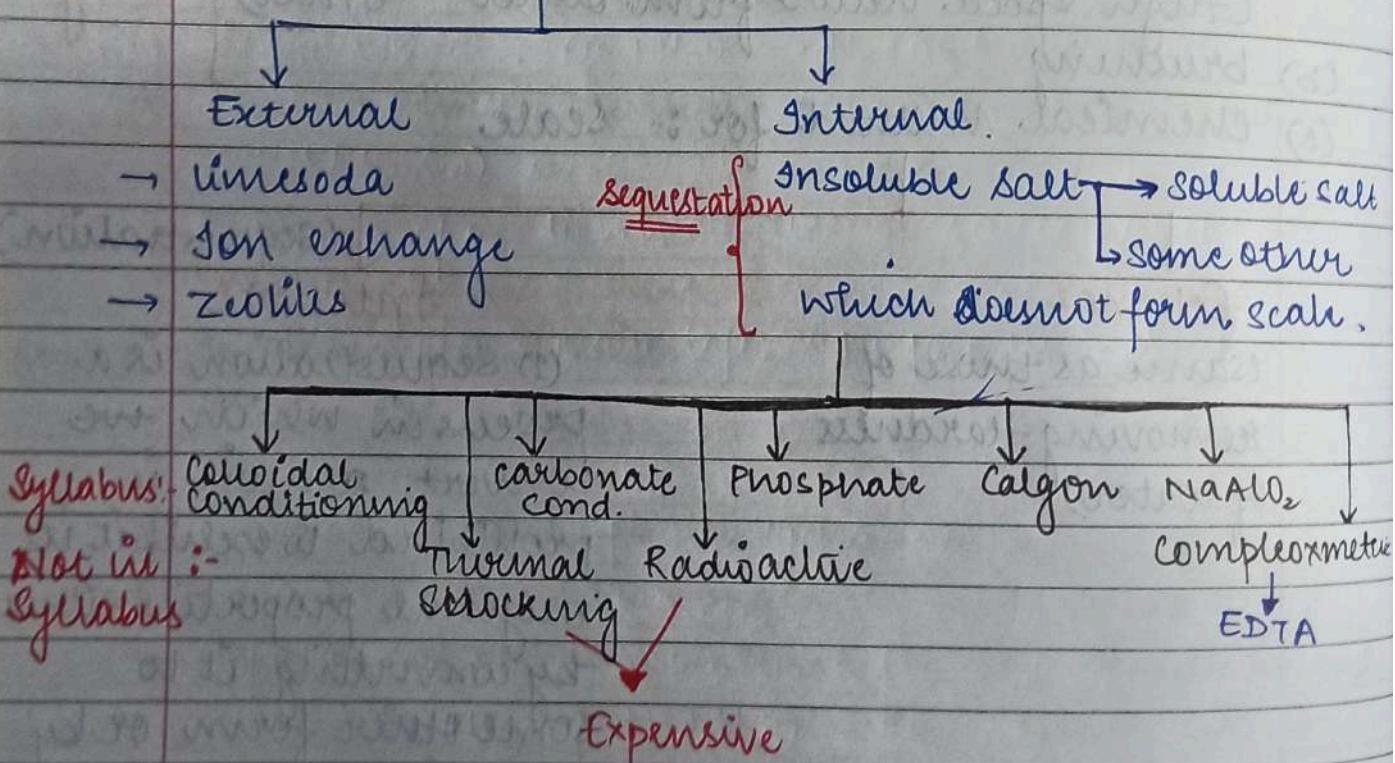
Scale :- Adhere tightly, hotter region of boilers,
due to salts insoluble in water, CaCO_3 , CaSO_4 , etc.

Due to continuous boiling of water, solute ↑ & solvent ↓
solute beyond saturation point \Rightarrow stick to the walls of
boilers.

Thermal conductivity is poor now \Rightarrow high energy
for req temp \rightarrow thermal shocking.

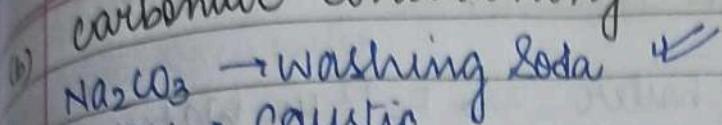
Removal (Reaction Temp)

(i) chemical methods

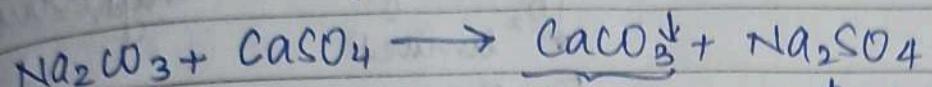


(a) Colloidal conditioning :- Add colloidal substance like Agar-Agar, Kerosene, forms slippery layer on Scale / sludge \Rightarrow \times coagulation

(b) carbonate conditioning

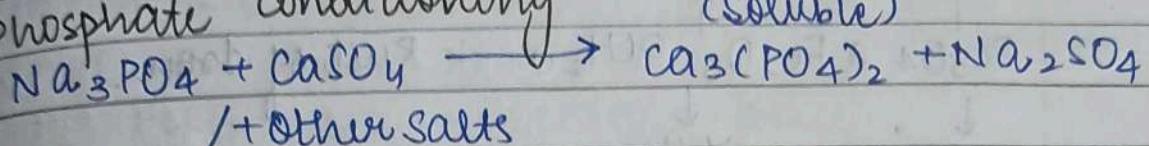


\rightarrow Baking soda (blowing agent)



Insoluble \rightarrow But soft sludge.

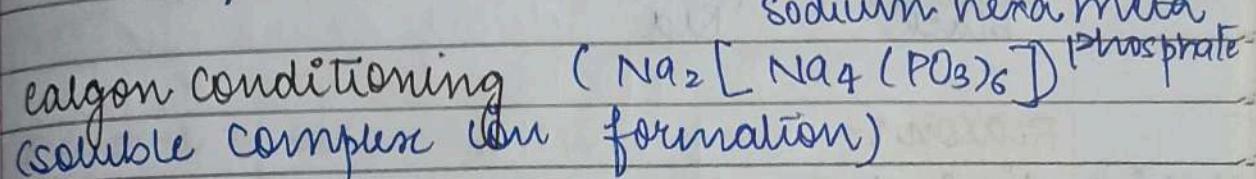
(c) phosphate conditioning



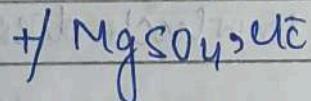
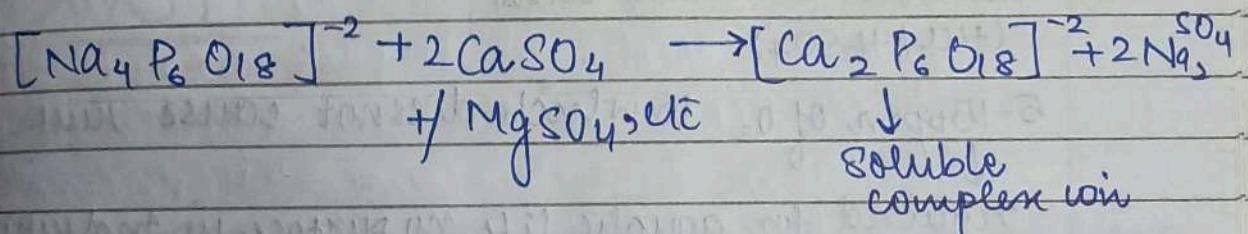
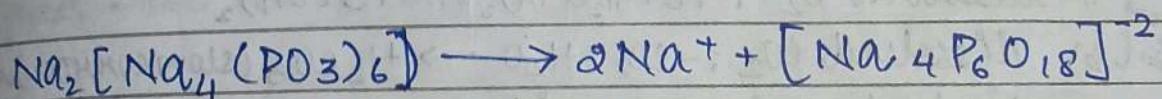
/ + Other salts

(soluble)

(d) calgon conditioning

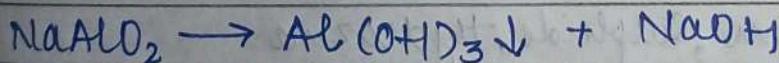


(soluble complex ion formation)

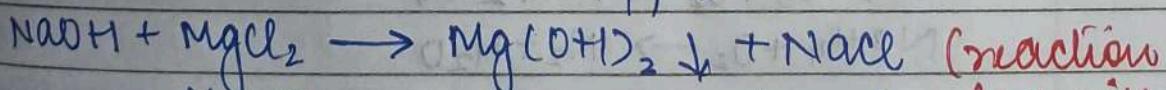


\downarrow
Soluble
complex ion

(e) NaAlO_2 .



+ H_2O (soft insoluble white gelatinous ppt)



Mg_2CO_3 (insoluble soft ppt) fast with

(less mud sludge)
(more scale)

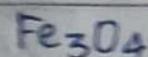
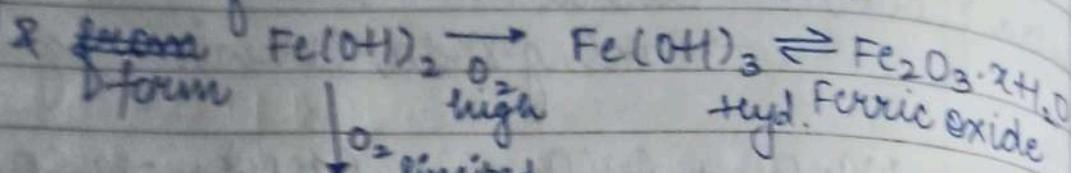
Mg^{2+} salts)

O₂ can corrode every metal
Strong Acid & base → fast corrosion

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BOILER CORROSION :-

At high T, Fe of boiler → Fe⁺² in water



magnetite Ferrous-O-Ferric oxide
↓ Hematite

Fe₃O₄ & Fe₂O₃ · 2H₂O : - Rust of Iron.

↓ Yellow
Reddish black Rust

REASON :-

- form a) dissolved O₂ : - Fe + H₂O + O₂ → Fe(OH)₂
- weak acid b) dissolved CO₂ : - CO₂ + H₂O → H₂CO₃ (slow corrosion bcz weak acid)
c) dissolved mineral acids
(HCl / H₂SO₄)

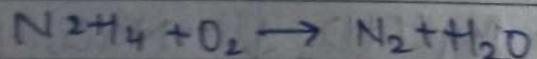
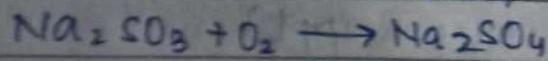
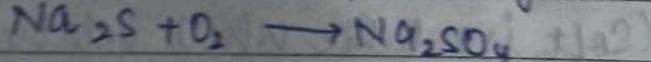
5-15 ppm of O₂ which does not cause rust.

required for aquatic life, no purpose in industries.

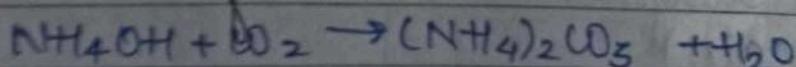
Remove extra O₂

a) Mechanical de-aeration

b) ~~Na₂S~~ Sodium Sulphide, Hydrazine



Removal of extra CO₂

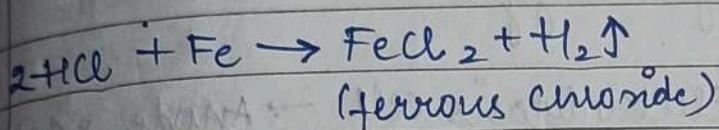
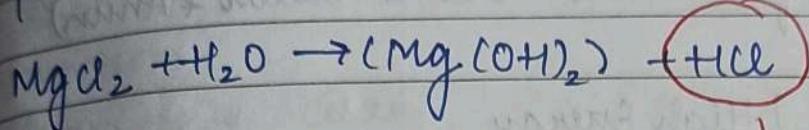


Mineral Acid (Sources)

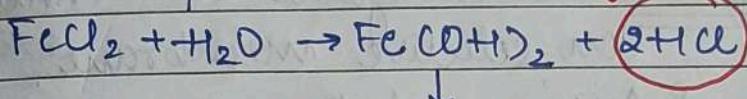
from Rain water.

from Industrial waste.

HCl can generate itself if Mg^{+2} salts are present in water.



accelerated reaction



↓
Rust of iron

Removal of mineral acid

a) Add base to neutralise water.

→ Deposition

CAUSTIC EMBRITTLEMENT

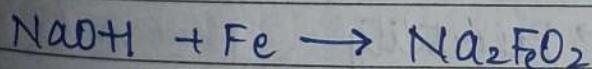
(Boiler corrosion)

Due to NaOH (corrosive to mild steel)

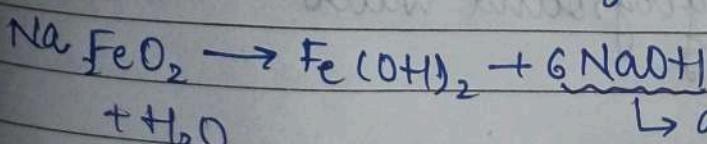
Unequal strain → heat generated → highly reactive in that area

Corrosion material in unequal strain area → caustic embrittlement.

NaOH deposit in hairlike cracks & react with Fe.



Sodium ferrate / hypoferrite



→ alkaline

Local accelerated, stress corrosion

Prevention

Add acid to neutralise

Date: 3-2-2023

Desalination of Water

remove salt from water (~~cation & Anion~~ cation & Anion)

26% Salt.

1) Freezing { High Energy

2) Distillation

* 3) Electrodialysis :- Electrodialysis cell → Anode & Cathode
Ion selective membrane.

Imp. Cation & Anion selective membrane.

migration to oppositely charged electrode.

↳ Ion free water

* 4) RO :- TDS < 1000 not required.

House water less than 200 TDS.

Membrane technology (SPM)

allow solvent molecules to pass & solute stay.

OSMOSIS :- concⁿ & dil soln , at osmotic pressure

water moves from high low concⁿ → high concⁿ

Hydrostatic pressure > osmotic from high to low.
membrane are not ion selective hence essential
Salts are also removed

→ defluorination :- Remove F from water.

High amount of F → bone weak

→ Infertility

→ Tooth decay

F is high in underground water

TREATMENT OF MUNICIPAL SUPPLY WATER

(Domestic / Portable)

Acc to water STD, (ISO 10500 series) & WHO guidelines
 WHO:- standards for safe drinking water (more restriction).

PHYSICAL :-

- a) Sparkingly clear
- b) Turbidity upto 10 ppm.
- c) Tasteless (Own taste only)
- d) Odourless.

CHEMICAL :-

- a) Hardness
- b) Alkalinity
- c) corrosion
- d) optimum value of Ca & Mg, Fe, Na, K, Manganese

↓
4.3 ppm 1
0.05 ppm

(Manganese impart colour & stain in clothes)

- e) pH → b/w 6.5 - 8 pH (WHO guidelines)
6.5 - 8.5 pH (ISO 10500)

If water is having natural salts it would be generally Alkaline hence $\text{pH} > 7$ is more in guidelines

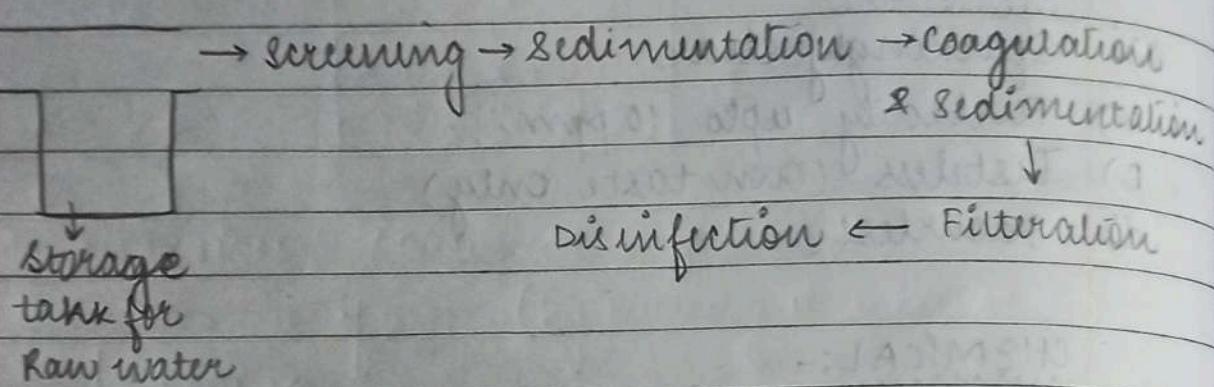
Above 8.5 pH \Rightarrow rupture mucus membrane

BIOLOGICAL :-

- a) Micro organism free
- b) bacterial

- c) Objectional heavy metal (Cr, ~~Ag~~, Fe, Pb, Hg, Zn)
 should not be present (In underground water in some regions)

We always require treatment done by municipality



(A) Screening

- D) Removal of insoluble floating ~~to~~
 wooden screens with holes.

(B) Sedimentation

- D) Sedimentation tanks → 8-10 hours → Large impurities settle down.

(C) Coagulation

- To settle impurities not done in sedimentation

Coagulants :- Potash Alum :- $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$

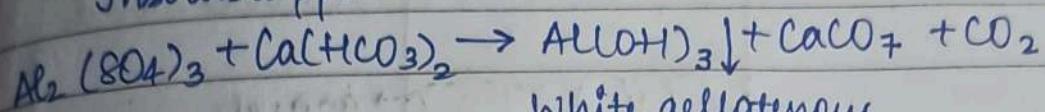
Sod. Aluminate :- $NaAlO_2$

Hydrate Ferrous Sulphate :- $FeSO_4 \cdot 7H_2O$
 (copperas)

Mechanism

flocculation / Neutralisation
(light ppt)
(Ca, Mg, Na, K salts)

↓
insoluble ppt



white gelatinous
ppt.

Air + 3 ions
(Neutralisation)

↓
insoluble impurities
adsorb on these
PPT

provide cation & Si, clay
are Anion

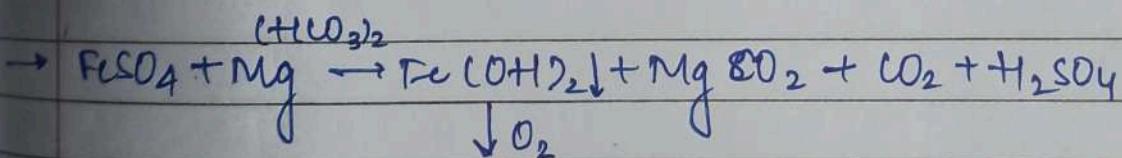
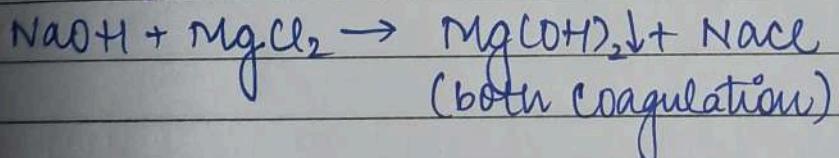
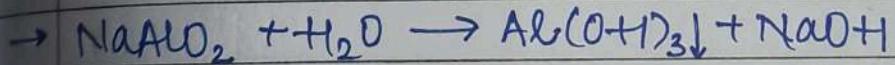
↓
light
float

+ heavy
settled down
(flocculation)

Attraction

↓
coalescence.

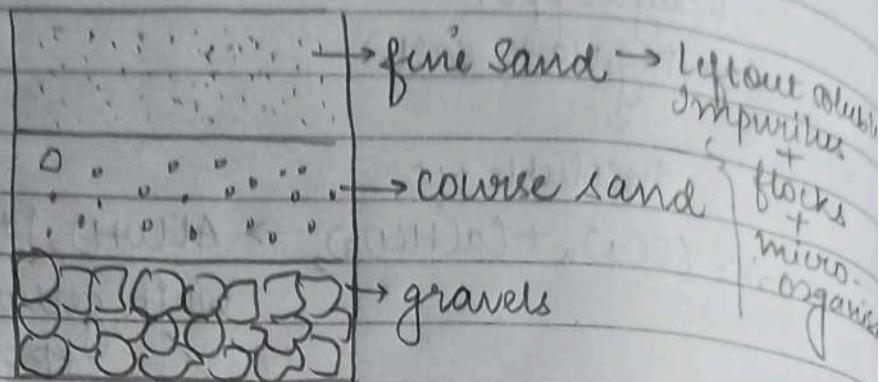
~~edge~~



$Fe(OH)_3 \downarrow$ (Neutralisation > flocculation)

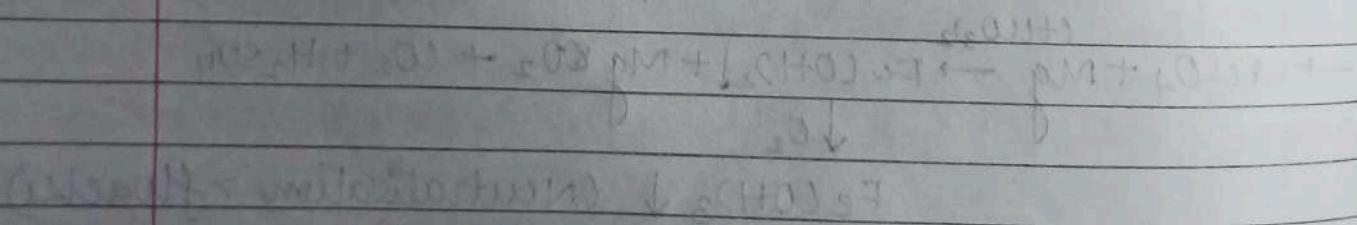
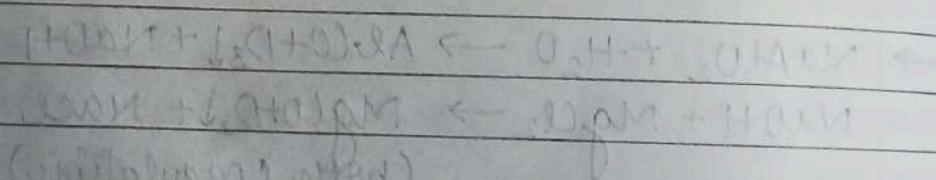
(D) Filtration :-

Natural soil filter (anap)
Three layers

(E) DISINFECTION :- (Biological impurities)

Sterilisation of water (by putting it in boil or etc)

- (Leave colour)
 - Boiling
 - KMnO₄ → Oxidise enzyme & deactivate metabolism
 - UV radiations
 - Ozone (O₃) → Oxidise enzyme & deactivate metabolism
 - Cl₂ * → Oxidise enzyme & deactivate metabolism
- (Strong Agent but not stable)



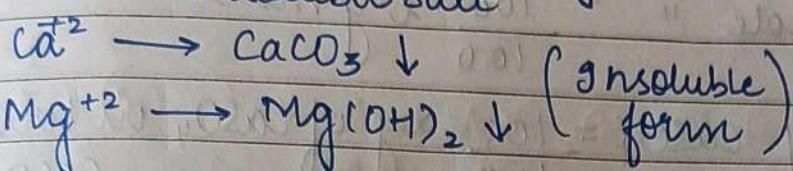
LIME-SODA PROCESS

Residual :- 50-60 ppm impurities.

Lime :- $\text{Ca}(\text{OH})_2$

Soda :- Na_2CO_3

Principle :- Soluble hardness producing salt after adding Soda lime \rightarrow Insoluble salt



Acid

Gases

coagulants

+ Lime soda \rightarrow Insoluble form.

Type of x mg/L of $\text{Ca}(\text{HCO}_3)_2$ salt. Amt of lime, Soda of question both required (y mg/L of CaSO_4)

1 mole of $\text{CaCO}_3 \equiv 1$ mole of $\text{Ca}(\text{OH})_2$

100 gram mole of $\text{CaCO}_3 \equiv 74$ gram mole of $\text{Ca}(\text{OH})_2$

$1 \text{ " } \text{CaCO}_3 = \frac{74}{100}$ gram mole of $\text{Ca}(\text{OH})_2$

$x \text{ " } \text{CaCO}_3 = \frac{74}{100} x$



x mg of $\text{Ca}(\text{HCO}_3)_2$ in terms of $\text{CaCO}_3 \equiv \frac{74}{100} x$

$$\frac{W}{e} \times 50 \times L/S$$

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Lime required :- $\frac{94}{100}$ [Amount of salt in terms of CaCO_3]
unit :- As in ques.

1 mole of CaCO_3 = 1 mole of Na_2SO_4

100g mole " = 106 g mole "

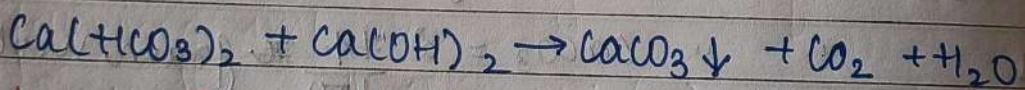
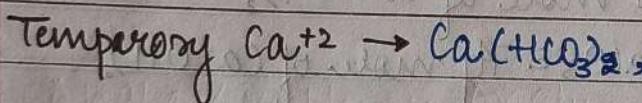
$$x \text{ g mole } " = \frac{106}{100} x \text{ g mole } "$$

y mg of $\text{CaSO}_4 = \frac{106}{100} xy$ of CaSO_4 , in terms of CaCO_3

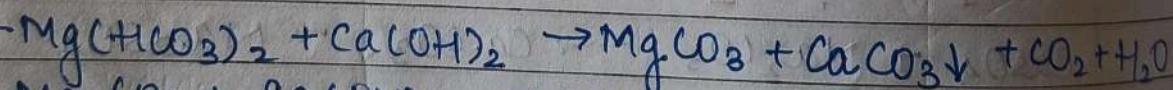
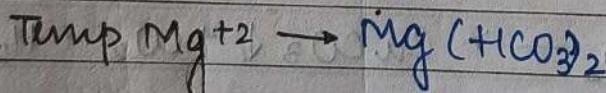
Soda Required :- $\frac{106}{100}$ [Amount of salt in
terms of CaCO_3]

Unit :- As in ques.

Impurity in Lime & Soda = Lime req. $\times \frac{100}{\% \text{ Purity}}$



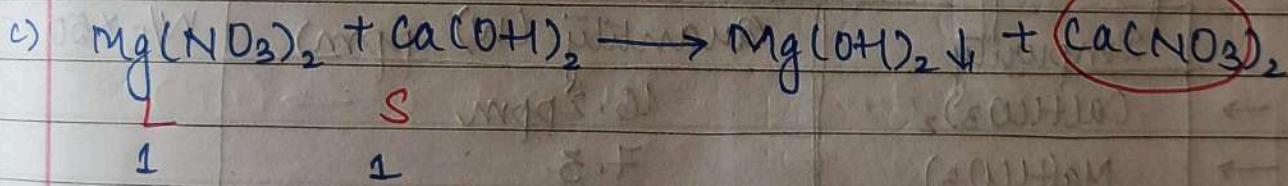
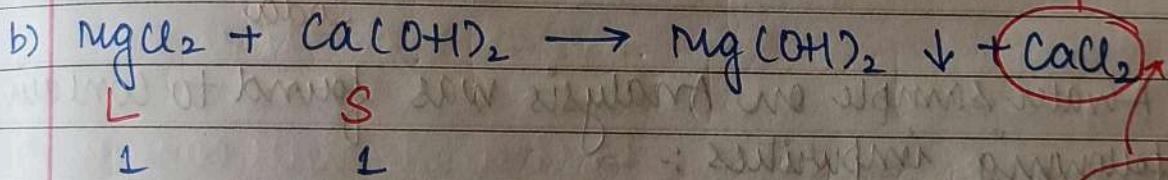
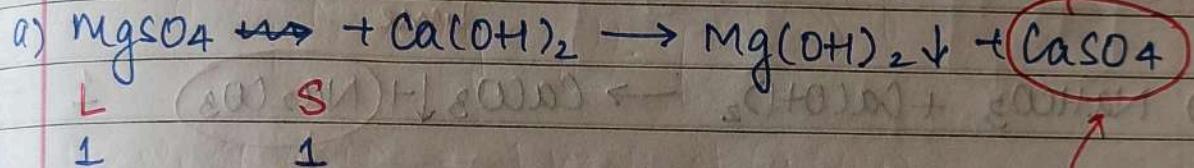
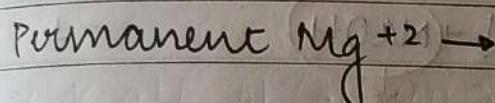
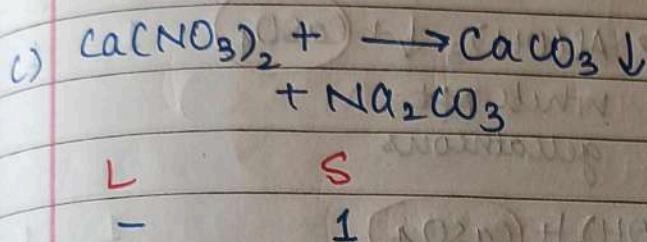
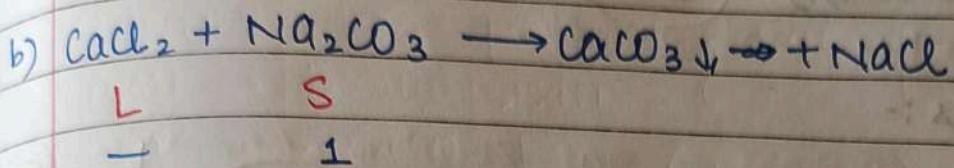
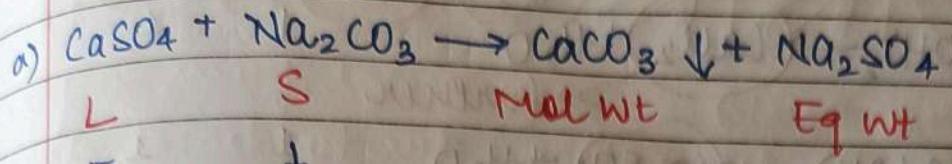
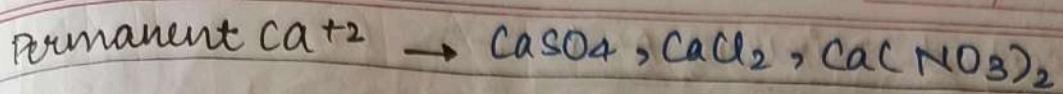
L	S	Mol wt	Eq wt
1	-		



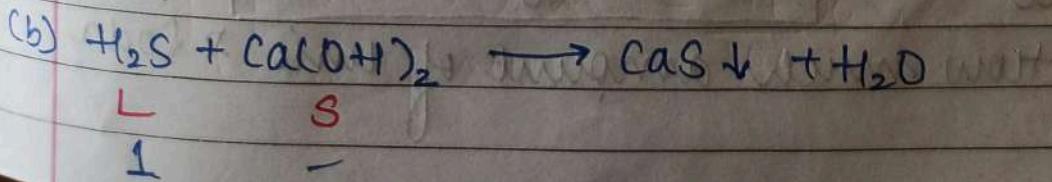
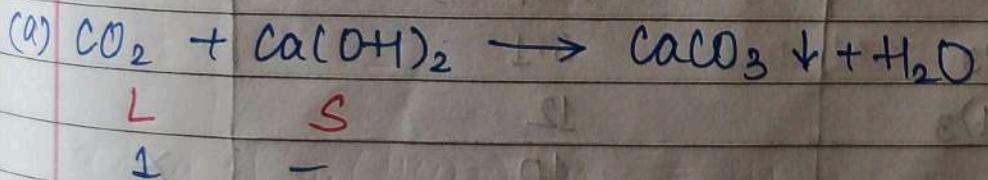
L	S	Mol wt	Eq wt
2	-		
1	-		

$$\frac{74}{100} (\text{CaCO}_3 \text{ equivalent}) \times \frac{\text{vol}}{10^6} \times \frac{100}{\% \text{ purity}}$$

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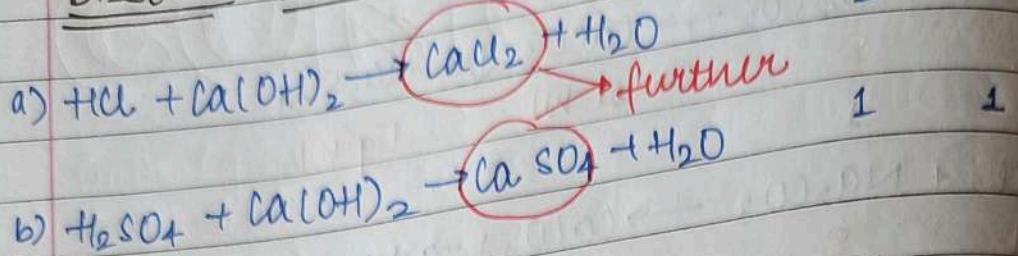
Dissolved Gases :-



n factor of $\text{CO}_2 \rightarrow 2$
 " " " " $\text{Al}_2\text{O}_3 \rightarrow 6$

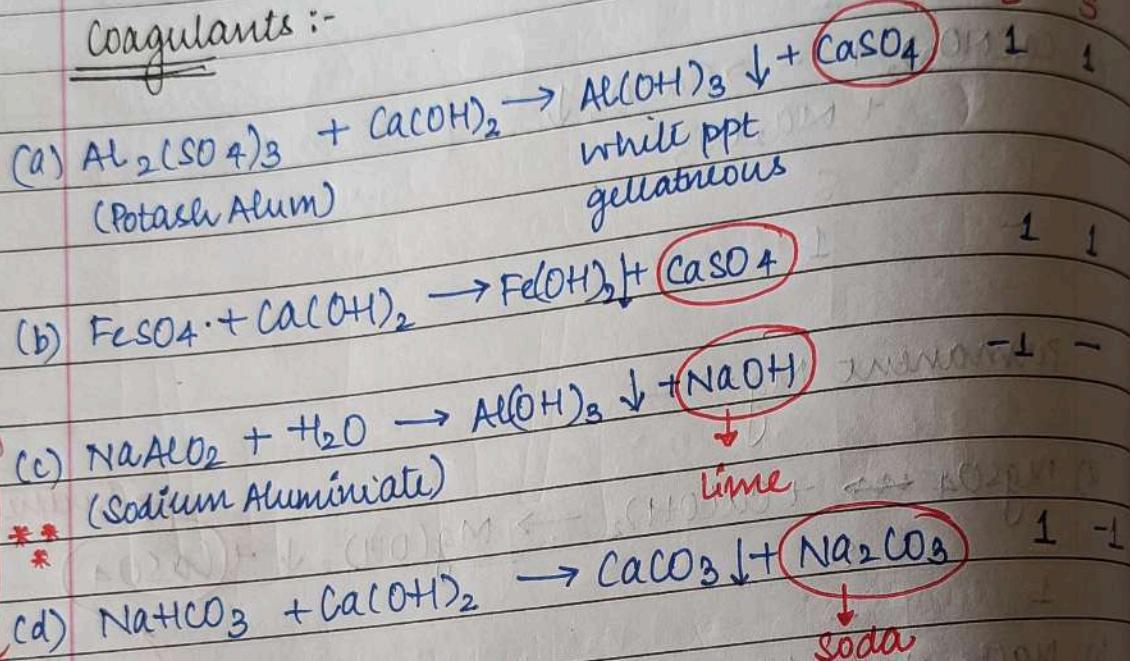
Equivalent wt of Potash Alum
 ↓
 Put a ~~ARTICLE~~ consider K_2SO_4
 for eqw weight.

Dissolved Mineral Acids :-



L S
 1 1

Coagulants :-



L S
 1 1

1 1

-1 -

1 -1

Q A water sample on Analysis was found to contain following impurities :-

Impurity	Quantity (W) (ppm)	W/E × 50
$\text{Ca(HCO}_3)_2$	16.2 ppm	
$\text{Mg(HCO}_3)_2$	7.3	
MgSO_4	12	
HCl	3.65	
CO_2	211	
Na_2CO_3	6.1	
$\text{Al}_2(\text{SO}_4)_3$	12	
NaCl	10	X

How much amount of lime & Soda

Ca^{+2} , Mg^{+2} , $\left\{ \begin{array}{l} +\text{CO}_3^{-} \\ \downarrow \\ \text{Na only} \end{array} \right\} \rightarrow$ equivalent wt of
Permanent \downarrow Na only ion only.

CLASSTIME Pg. No.
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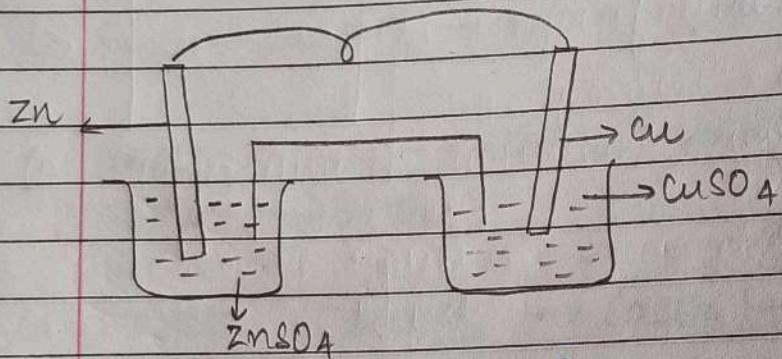
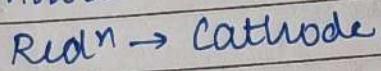
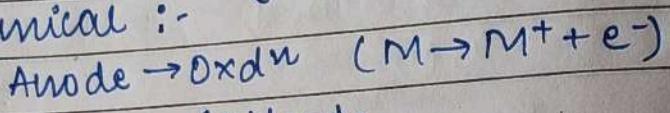
will be req. for softening of 1 liter l of such water.
The lime is 90% pure & soda is 85% pure.

CORROSION

CuCO_3 (green rust) on metal from surface
 destruction or deterioration due to direct chemical
 or electrochemical attack.

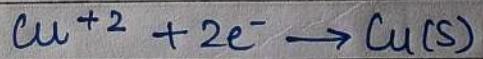
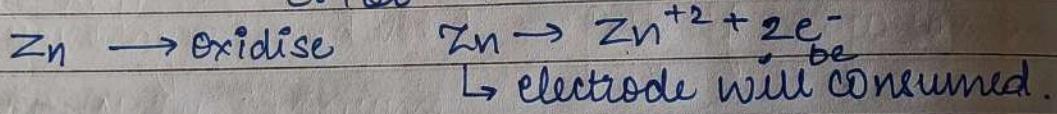
chemical contact :- gas, solution (O_2 , H_2O , etc)

Electrochemical :-



E.Potential -ve \rightarrow Oxidation

E. Pot +ve \rightarrow reduction



If this process is done unintentionally \rightarrow corrosion

conc \uparrow \rightarrow anode \rightarrow corrosion on anode.

conc \downarrow \rightarrow cathode

Q Why metal corrodes?

A Highly Reactive. Metals are thus impure in earth crust also. Metal have tendency to react & form a compound on surface. \Rightarrow corrosion

Effect :- (of corrosion)

(a) Contamination (+ Impurity) of metal
 $\text{Iron} \rightarrow \text{Iron oxide}$

properties changes. $\Rightarrow \eta \downarrow$, production rate \downarrow
 (b) Destruction of metal.

(c) Machinery $\eta \downarrow$

Prevention :-

Paint, electroplating, etc

Types of corrosion

Chemical / Dry

Electrochemical / Wet
 corrosion

\rightarrow This type of corrosion occurs when metal comes in contact with some gas, chemical or some anhydrous liquid (Inorganic)

Oxidation

corrosion by

O_2 . O_2 is oxidized

to every metal.

Oxd in presence

of O_2 & absence of moisture

other gases

other than O_2

\rightarrow Reactivity of gas w metal

\rightarrow Type of film

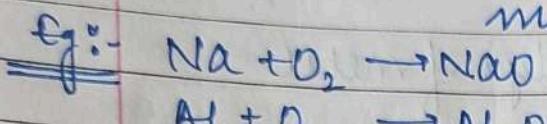
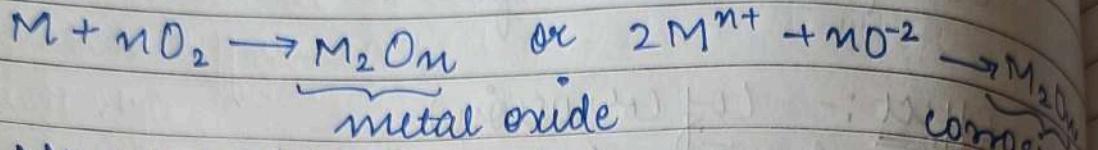
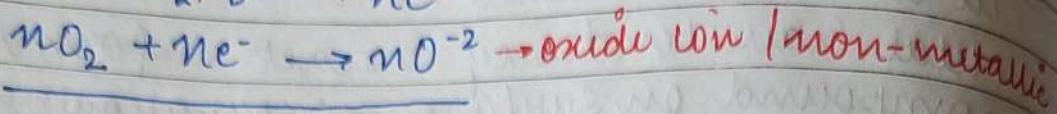
liquid Metal

(Cu, Fe)

Alkaline earth & Alkali metal

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Oxidation corrosion :-
 → metallic ion



- (1) Stable film (ii) Unstable (iii) Volatile (iv) Porous

Protection

Protective

Non-Protection

↓ further corrosion ✗

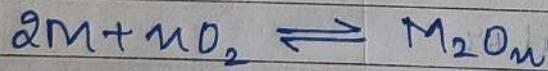
↓ further corrosion ✗

→ STABLE :-

hard layer, void vol ↓ → Rate of corrosion ↓

Eg:- Al, Cu, Titanium

→ UNSTABLE :-



no net reaction

Protective Eg:- Silver, Au, Pt.

No oxidation → expensive → jewellery making

→ volatile :-

vaporise in environment → re-corrosion → re-vapourisation

Eg:- MoO₃ (molybdenum)

→ Porous :-

not a continuous film of oxide

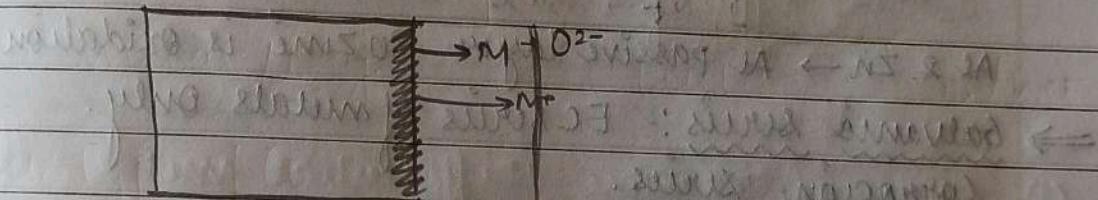
Size of Poros \propto Rate of corrosion

Peeling bedworth Rule :- for porous
(rate of further corrosion)

States that higher the specific vol ratio
lesser is the rate of further corrosion &
vice versa.

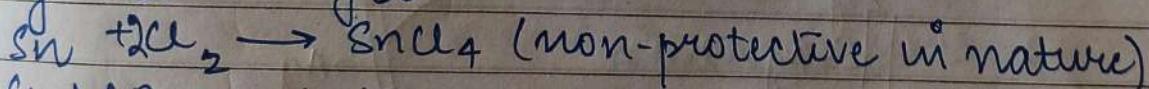
$$\text{specific vol} = \frac{\text{vol of Metal Oxide}}{\text{vol of metal}} = \frac{\text{vol of metal - Poros}}{\text{vol of metal}}$$

New film :- above old film or after old film?
decided by mobility (mobility \propto 1/size)
L size of ion M size \times N M size.
hence new film over old film.



OTHER GASES :-

$\text{Cl} \rightarrow \text{Ti} / \text{Ag}$ (High Reactivity)



LIQUID METAL CORROSION:-

Solid metal in contact w/ liq metal liq flows
over solid \rightarrow solid metal gets corroded

(a) penetrate or (b) deterioration

Eg:- Nuclear reaction
 Cadmium + lq Na \rightarrow corrosive
 (coolant)

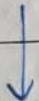
Date - 10 Feb 2023

\rightarrow Electrochemical corrosion
 when 2 diff are connected with each other * with
 electrolyte & electrodes

OR

one electrode is connected with electrolyte with
 diff concn.

\Rightarrow Electro-chemical series :- \downarrow Oxdⁿ pot, \uparrow red pot
More Reactive \uparrow Li Electro⁺
 oxd pot = -ve \rightarrow easily oxidized
 + EP = 0

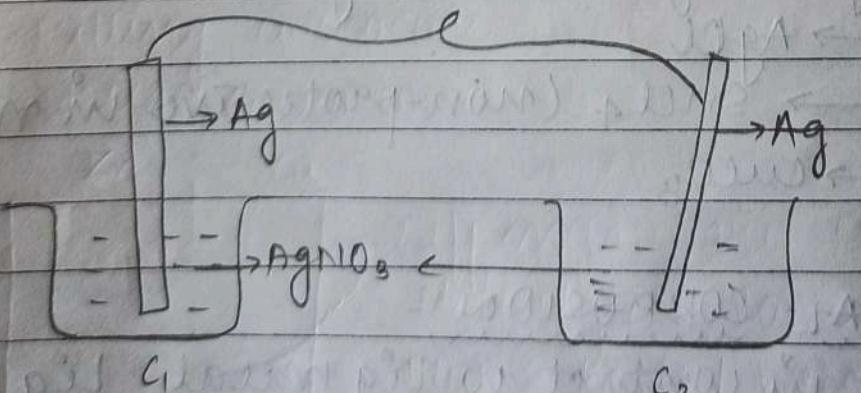


F

Al & Zn \rightarrow Al passive layer so zinc is oxidation

\Rightarrow Galvanic series :- EC series of metals only.
 Corrosion series.

↑ always corrode \Rightarrow anode



+ high concⁿ \rightarrow low concⁿ

humidity & ROR

CLASSTIME Pg. No.
Date

+ High concⁿ of O₂ → Cathode



water → oxidation pot ↑ → liberate e⁻
e⁻ consumed by surroundings (O₂, acidic vapours)

At Anode :- Oxidation



→ form surface compound
or

→ Dissolve into environment

Cathode :- Reduction :-

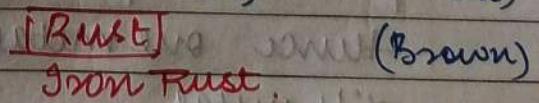
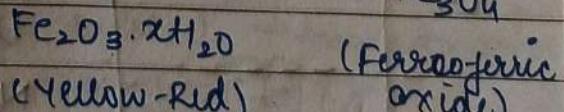
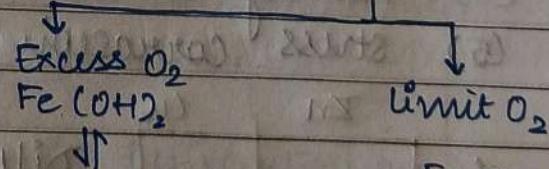
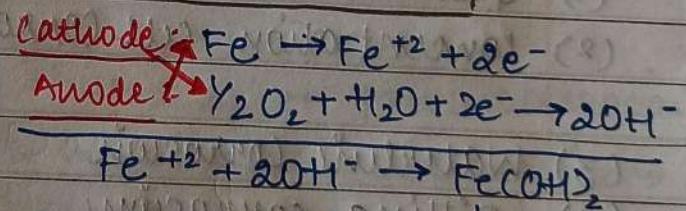
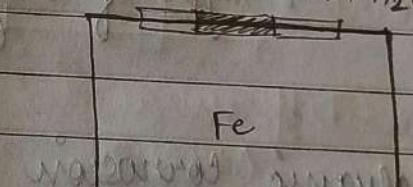
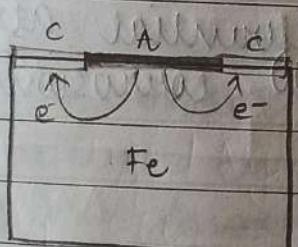
(i) By evolution of H₂
(Acidic environment)

(ii) By absorption of O₂
(O₂ & H₂ in environment)

Anode :- Fe → Fe⁺² + 2e⁻

Cathode :- 2H⁺ + 2e⁻ → H₂↑

+ 2e⁻



→ concn ↑ → Anode.
(HCl)

→ Formation of several
cathodes & Anodes.

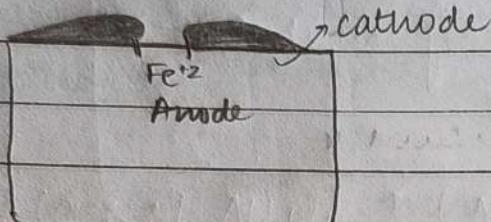
Overall Reaction
→ Fe + 2H⁺ → Fe⁺² + H₂↑
Fe⁺² dissolves in HCl →
Loss → corrosion.

Q

Where corrosion product gets deposit?
Depends upon mobility of ion.

Size m < Size nm

Mobility m > Mobility nm



Q

Anode Area of (ii) < Anode Area of (i)
Strong Acid (+ve) attacks large area

Q.

Rate of Reaction in (ii) & (i)?

(ii) \rightarrow (i) small area \Rightarrow electron density ↑ \rightarrow fast
cathode ↑ \rightarrow more consumption of e^- movement of e-

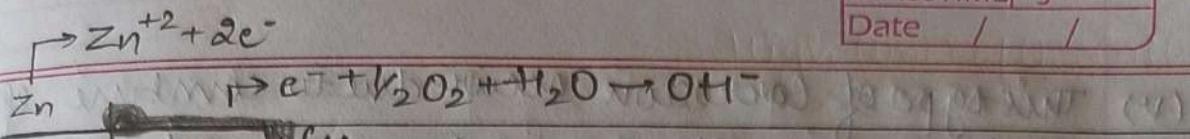
-: Types of electro-chemical corrosion :-

- (1) Galvanic corrosion / Differential metal ^{Diff metals} are connected
- (2) Concentration cell corrosion / Differential aeration corrosion.
- (3) Waterline corrosion
- (4) Pitting corrosion
- (5) Stress corrosion

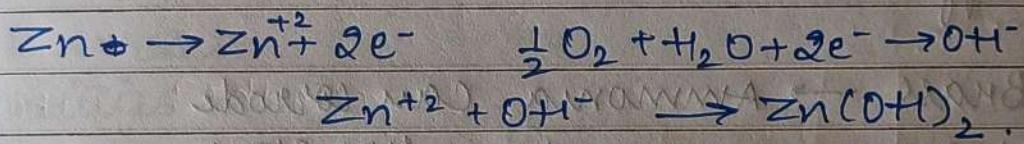
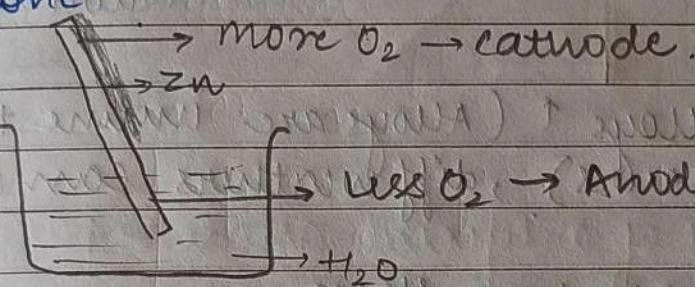
	En	Cu
(i)		
(ii)		

Diff metals are connected with electrolyte & each other.

Nut & Bolts / welding \rightarrow E.c corrosion
hence one metal in one design, avoid using diff metal.

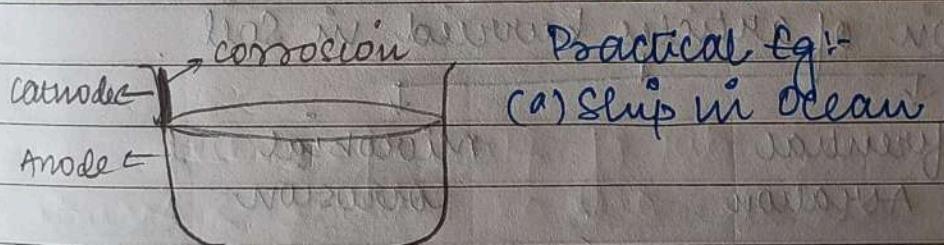


(ii) single metal in contact with electrolyte with diff concn



(iii) case of (ii)

water in metal tank (steel, Fe)

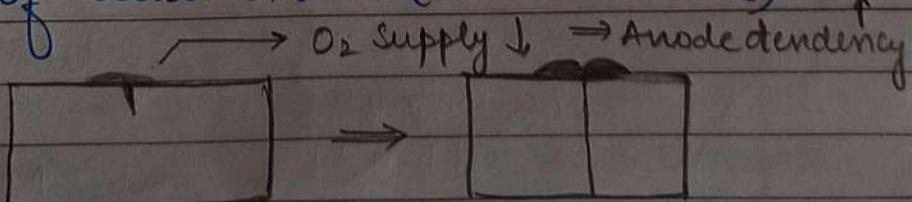


(iv) Stable metal layer by humans \rightarrow prevent corrosion
minute cracks due to any factor $\Rightarrow H_2O$ deposit $\Rightarrow O_2 \downarrow \rightarrow$ Anode (pitting like hole) (small Anode)

\rightarrow chemical attack

\rightarrow mechanical forces

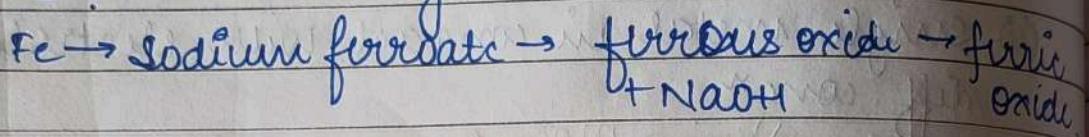
\rightarrow uneven layer of metal oxide (uncontinuous)



(v) This type of corrosion occurs due to combined effort of static tensile stress & a corrosive agent.

Eg:- Caustic embrittlement.

Ununiform stress \rightarrow uneven strain \rightarrow minute cracks \rightarrow attacked by NaOH



In case of Alloys ↑ (Alloys are immune to corrosion but this occurs), diff weathers can cause cracks

diff metals \Rightarrow uneven stress,

Brass \rightarrow Ammonia can corrode

NaOH \rightarrow can corrode milled steel.

SOIL CORROSION:-

corrosion of articles buried in soil

Differential
Aeration

(CO₂ & H₂O)

microbial
corrosion

due to microorganism

Bacteria mainly

Aerobic

consumes O₂
becomes anode

Anaerobic

generate acid
conc ↑ (acid)

FACTORS AFFECTING CORROSION

(a) Nature of metal

impurity \propto corrosion

passivity of metal

position of metal in Galvanic series

(b) Nature of environment

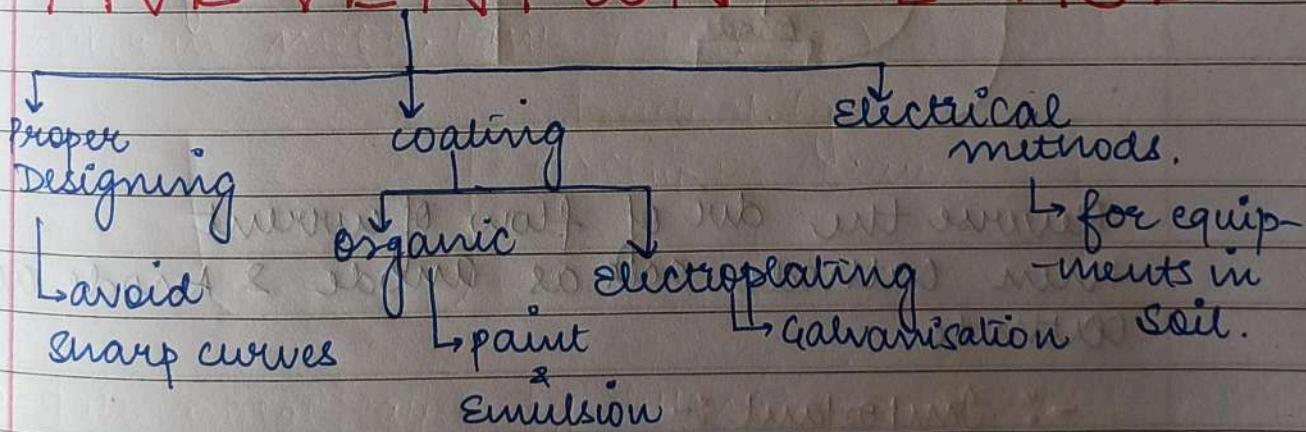
Temp (corrosion is a chem reaction)

humidity (corrosive agent)

pH (corrosion \uparrow in acidic medium & strong alkali)

Impurities

PREVENTION METHODS:-



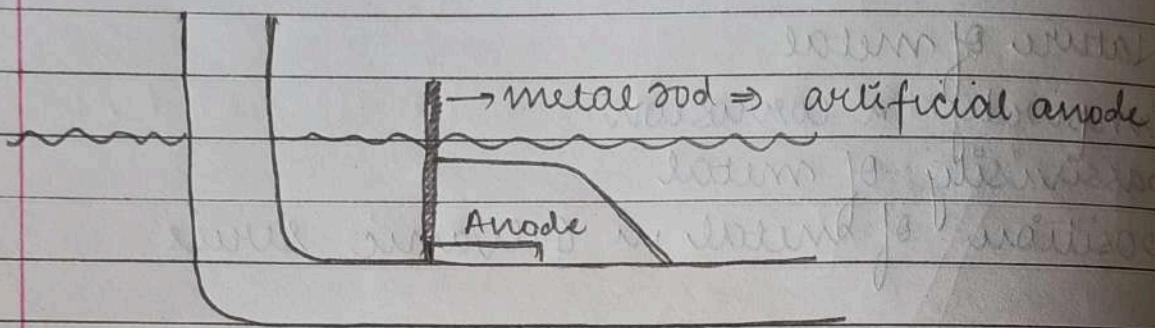
\Rightarrow we should avoid coating of anode \rightarrow layer break
 at anode after some time \rightarrow small anode \rightarrow
 large corrosion

Electrical method

Sacrificial anodic protection method

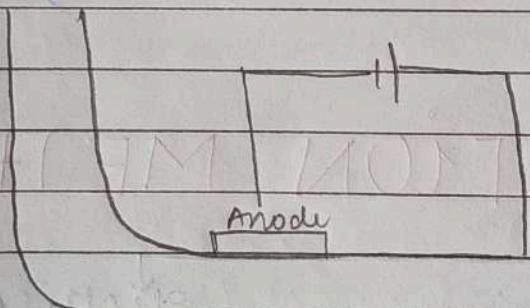
Impressed current cathodic protection

SAPM :- protecting parent Anode by substituting a new anode.



Oxidation pot of artificial anode > parent anode

ICCP :-



Reverse the dir. of flow of current
then cathode acts as anode & anode acts as cathode.

- :- Important :-

Oxidation corr much.

Electrochem mech

Prevention electrochem mech

GREEN TECHNOLOGY

* { what
12 principles

Atom economy

Rearrangement & oxidation Reaction

Innocuous solvent.

Design, manufacture, dispose off, use should be
environment friendly

Five R