

Engineering chemistry - Isubject code : CY8151unit - I water and its treatmentIntroduction

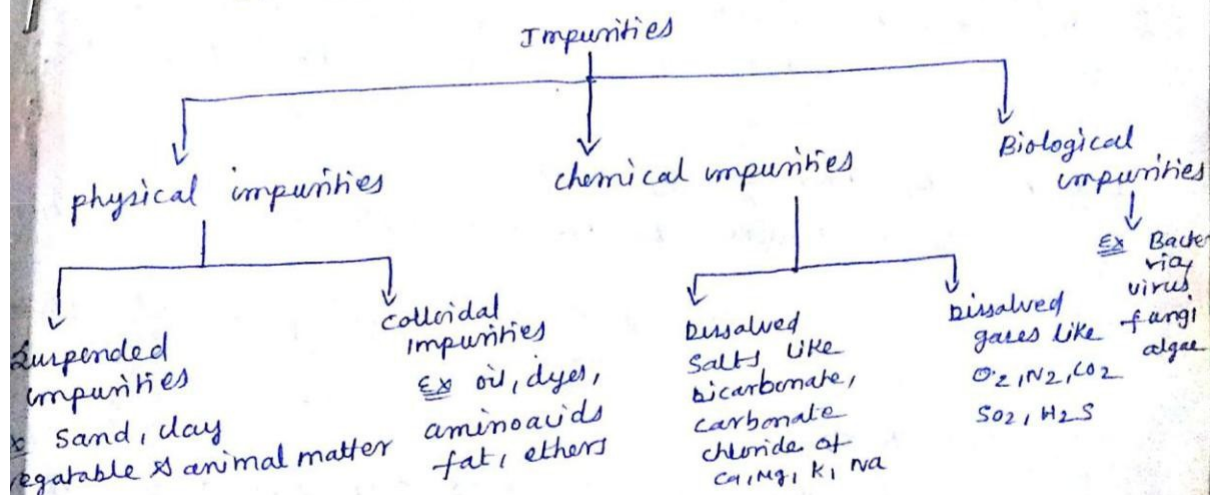
- ✓ water is the most essential for all living beings on the earth.
- ✓ Hence without water, there is no life on the earth.

Sources of water

- i) natural water - Rain water
- ii) Surface water - Rain water, river water, lake water & sea water
- iii) underground water - Spring water and, well water

Types of impurities

It can divided into three types

Hardness of water

The presence of dissolved salts like bicarbonates, chlorides and Sulphates of calcium and Magnesium.

Types of water

1. Soft water
2. Hard water

Soft water:

- i) It gives good lather with soap solution is called Soft water.
- ii) the absence of dissolved salts of Ca & Mg

Hard water:

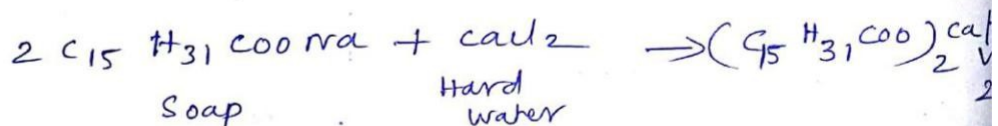
- i) It does not give good lather with soap solution is called as hard water.
- ii) the presence of dissolved salts of Ca & Mg

Difference between Soft water & Hard water

<u>Soft water</u>	<u>Hard water</u>
1. It gives good lather with soap solution	It does not give good lather with soap solution
2. Absence of dissolved salts of Ca & Mg	presence of dissolved salts of Ca & Mg
3. It ^{does not} give wine red colour with Eriochrome black-T indicator.	It gives wine red colour with Eriochrome black-T indicator.

Detection of hardness of water

It is detected by treating water with soap solution

Types of hardness

The types of dissolved salts present in water are classified into two types.

1. Temporary hardness
2. permanent hardness

Temporary hardness

The presence of bicarbonates salt of Ca & Mg called as Temporary hardness of water

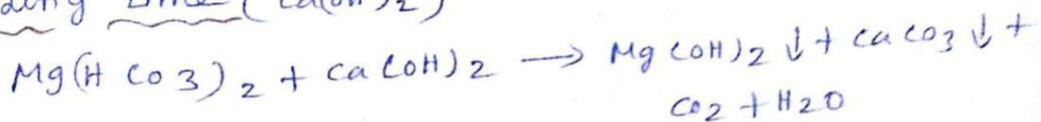
carbonate hardness of water (or) alkaline hardness of water.

Removed by

i) boiling the water



ii) Adding Lime (Ca(OH)_2)



permanent hardness of water

The presence of chlorides and sulphates of Ca & Mg called as permanent hardness of water (or) non-carbonate hardness of water (or) non-alkaline hardness of H_2O

Removed by

i) Lime soda process $\rightarrow \text{CaCl}_2 + \text{Na}_2\text{CO}_3 \rightarrow \text{CaCO}_3 \downarrow + 2\text{NaCl}$

ii) Zeolite process (Na_2Ze)



Total Hardness of water = Temporary Hardness + permanent hardness.

Differences between carbonate and non-carbonate hardness of H_2O

carbonate
The presence of bicarbonates of Ca & Mg

It can be removed by boiling the water

Another name is alkaline hardness

non-carbonate

The presence of chlorides and sulphates of Ca & Mg

It cannot be removed by boiling the water

Another name is non-alkaline hardness.

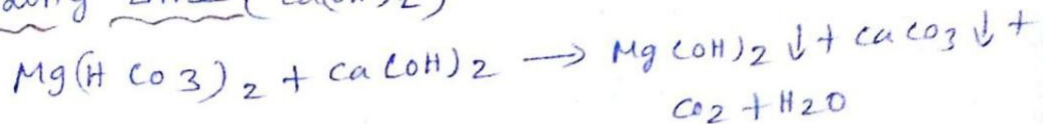
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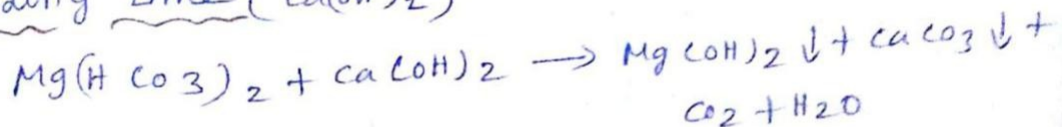
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Removed by

i) boiling the water



ii) Adding Lime (Ca(OH)₂)



permanent hardness of water

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non-carbonate

The presence of chlorides and sulphates of Ca & Mg

It cannot be removed by boiling the water

Another name is non-alkaline hardness.

Expression of hardness of equivalent of CaCO_3 standard

- i) Molecular weight is 100 and equivalent weight is 50. Hence, the calculations in water are simple and easy.
- ii) CaCO_3 is the most insoluble salt that can be precipitated during water treatment.
- iii) The amount equivalent of CaCO_3 = $\frac{\text{Amount of hardness producing salt} \times \text{Molecular weight of } \text{CaCO}_3}{\text{Molecular weight of hardness producing salt}}$

<u>Hardness producing salt</u>	<u>Molecular weight</u>
Mg^{2+}	24
$\text{Mg}(\text{HCO}_3)_2$	146
Ca^{2+}	40
$\text{Ca}(\text{HCO}_3)_2$	162
MgCl_2	95
CaCl_2	111

Units of Hardness

- i) parts per million (PPM)
The number of parts of CaCO_3 equivalent hardness per 10^6 parts of water
- ii) Milligrams per Litre (mg/L)
The number of milligrams of CaCO_3 equivalent hardness per litre of water
 $1 \text{ mg/L} = 1 \text{ PPM}$
- iii) Clark's degree (°Cl)
The number of parts of CaCO_3 equivalent hardness per 70,000 parts of water

iv) Degree French (° Fr)

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The number of parts of CaCO_3 equivalent hardness per 10⁵ parts of water

v) Milliequivalent per Litre (meq/L)

The number of milli equivalents of hardness present per litre.

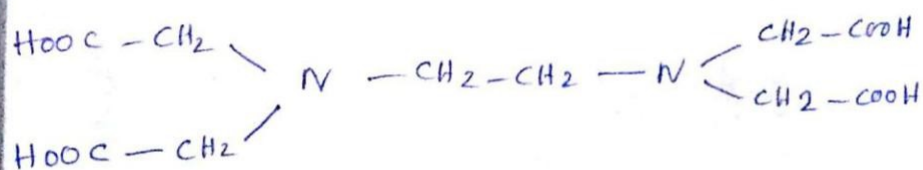
Estimation of Hardness of water by EDTA method

* It is a complexometric method.

* It is more accurate, convenient and fast.

* It is widely used for the estimation of hardness of H_2O .

EDTA $\rightarrow$ Ethylene Diamine Tetra Acetic acid.



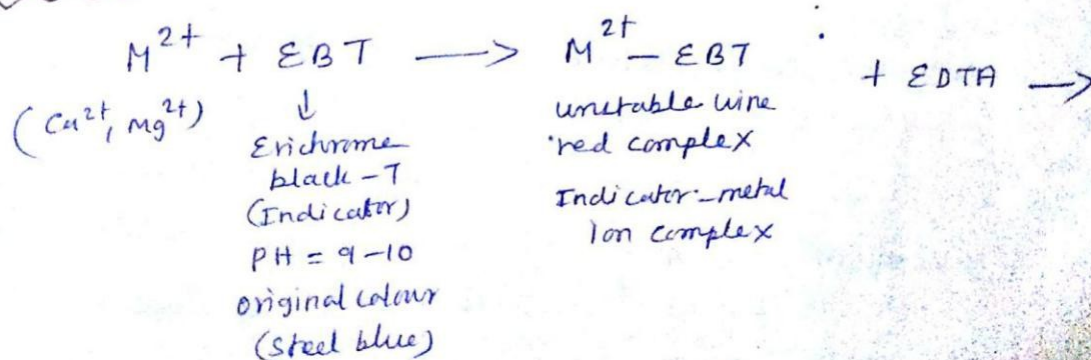
* EDTA is insoluble in water.

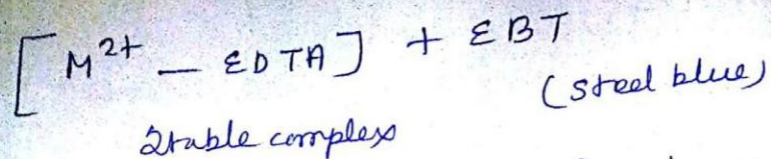
* Disodium salt (Na_2EDTA) is soluble in water.

* It is used as complexing agent.

* EDTA form stable complexes with Mg^{2+} & Ca^{2+} ions of hard water.

principle





* ~~with~~ Buffer solution $\rightarrow$ maintain constant pH value
 $\rightarrow$ ex: $NH_4Cl - NH_4OH$ mixture is added.

End point $\Rightarrow$ wine red $\rightarrow$ steel blue (Indicator colour)

preparation of solutions

- i) Standard hard water $\rightarrow$ 1g dry $CaCO_3$ + $dist. H_2O$ + 1000 ml of H_2O
- ii) EDTA solution $\rightarrow$ 4g EDTA + 1000 ml of H_2O
- iii) EBT indicator $\rightarrow$ 0.5 g EBT + 100 ml methanol
- iv) Buffer solutions $\rightarrow$ 67.5 g NH_4Cl in 570 ml NH_4OH + 1000 ml of H_2O

procedure

- i) Standardization of EDTA solution using standard hard water

Burette solution	- EDTA
Pipette solution	- 50 ml of std. hard water
Other solution	- 10 ml Buffer solution
Indicator	- Erichrome black-T
End point	- wine red $\rightarrow$ steel blue colour

calculation

Volume of EDTA = V_1 ml

1 ml of std. Hard water = 1 mg of $CaCO_3$

50 ml of std. " = 50 mg of $CaCO_3$

50 ml of " " requires V_1 ml of EDTA

V_1 ml of EDTA = 50 mg of $CaCO_3$

1 ml of EDTA = $\frac{50}{V_1}$ mg of $CaCO_3$

i) Estimation of total hardness of water sample using standardised EDTA solution

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Burette solution - EDTA
 Pipette solution - 50 ml of sample water
 other solution - 10 ml of Buffer solution
 Indicator - Eriochrome black-T
 End point - Steel blue colour

Calculation.

$$\text{Volume of EDTA} = V_2 \text{ ml}$$

50 ml of given sample water consumes = V_2 ml of EDTA

$$1 \text{ ml of EDTA} = \frac{V_2 \times 50}{V_1} \text{ mg CaCO}_3$$

$$\therefore 100 \text{ ml of given Sample water} = \frac{V_2 \times 50}{V_1} \times \frac{1000}{50}$$

$$= 1000 \frac{V_2}{V_1} \text{ mg CaCO}_3$$

$$\text{Total hardness} = 1000 \frac{V_2}{V_1} \text{ ppm}$$

i) Estimation of permanent hardness of water sample using standardised EDTA solution

- 100 ml sample water in 250 ml of Beaker
- Boiled for temporary hardness cool and filter and make up into 100 ml SMF.

a) Burette solution = EDTA
 Pipette solution = 50 ml Boiled sample water +
 other solution to be added = 10 ml of Buffer solution
 Indicator = Eriochrome black-T
 End point = Steel blue colour

Calculation

$$\text{Volume of EDTA} = V_3 \text{ ml}$$

$$50 \text{ ml of sample water consumes} = V_3 \text{ ml of EDTA}$$

$$1 \text{ ml of EDTA} = \frac{V_2}{V_1} \times \frac{50}{V_1} \text{ mg of CaCO}_3$$

$$\therefore 1000 \text{ ml of given sample water consumes } y = V_3 \times \frac{50}{V_1} \times \frac{1000}{50}$$

$$= 1000 \frac{V_3}{V_1} \text{ mg of CaCO}_3$$

$$\text{permanent hardness} = 1000 \frac{V_3}{V_1} \text{ mg of CaCO}_3$$

$$= 1000 \frac{V_3}{V_1} \text{ ppm}$$

$$\text{Temporary hardness} = \text{Total hardness} - \text{permanent hardness}$$

$$= 1000 \times \frac{V_2}{V_1} - 1000 \times \frac{V_3}{V_1}$$

$$= \frac{1000}{V_1} (V_2 - V_3) \text{ ppm}$$

Boiler feed water

Definition

The water fed into the boiler for the production of steam is called boiler feedwater. The water containing dissolved salts, gases and suspended impurities are used in boilers the following

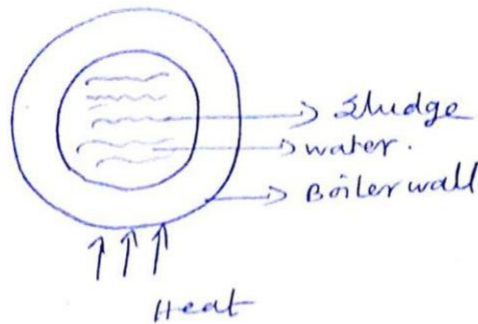
problems are

- 1) Scale and Sludge formation
- 2) boiler corrosion
- 3) caustic embrittlement
- 4) priming and foaming

Boiler troubles (on Scale and Sludge formation)

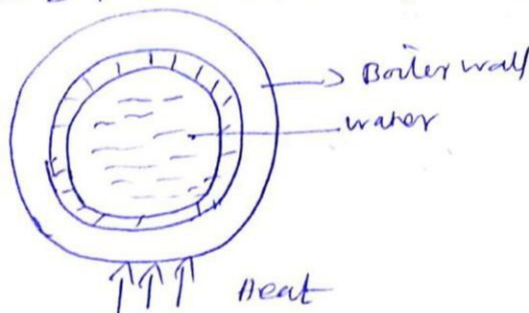
As water evaporate continuously in boilers for steam production, the salts precipitated on the inner walls of the boilers. Sludge → If the precipitate formed is soft and silvery it is called Sludge. It is formed by MgCl_2 , MgCO_3 , MgSO_4 & CaCl_2 .

They have greater solubilities in hot water than cold water



Scale 1. → If the precipitate is hard and adhering on the inner walls it is called scale.

2. → Scales are formed by substances like $\text{Ca}(\text{HCO}_3)_2$, CaSO_4 , & $\text{Mg}(\text{OH})_2$



Removal of Sludge (or) prevention of Sludge

1. Sludges are poor conductors of heat
2. Its formation can be prevented by using soft water
3. They can be removed by blow down operation method.

properties of Scales

1. Scales are poor thermal conductors, Hence they act as partial heat insulators results in wastage of fuels.

2. Over heated and produce large amount of steam and high pressure and explosion of boiler.

Removal of Scales

1. Brittle scales may be removed by giving thermal shocks.
2. Loosely sticking scales can be removed by scraping.
3. Firmly sticking scales can be removed by chemical reactions.

Comparison of Sludge and Scale

<u>Sludge</u>	<u>Scale</u>
1. It is a soft, loose & slimy precipitated	It is hard and adherent coating.
2. It is formed by substances like $MgCl_2$, $MgCO_3$, $MgSO_4$, $CaCl_2$	It is formed by substances like $Ca(HCO_3)_2$, $CaSO_4$, $Mg(OH)_2$
3. It is a poor conductor of heat	It is a thermal insulator
4. Decrease the efficiency of boiler	Decrease the efficiency of boiler and may cause boiler explosion.
5. It can be removed by scraping off with a wire brush	It may be removed by giving thermal shocks, scraping, chemical treatment
6. Wastage of fuel is very large $\rightarrow$	Wastage of fuel is comparatively less.
7. Methods for removal of Sludge I) Blow down operation II) Scraping by wire brush	Methods for removal of Scales I) Internal & external treatment

Softening or conditioning processes

Definition

Hard water is converted into soft water is called softening or conditioning processes.

Types of process

1. Internal conditioning processes
2. External " "

External conditioning process

1. It is carried out before its entry into the boiler.
2. It is preventive method
3. High pressure boilers require this treatment.
4. It includes lime soda process, zeolite (permutit) process and ion exchange process.

Internal conditioning process

1. It is carried out in the boiler itself.
2. It is a corrective method.
3. ^{Low} ~~High~~ pressure boilers require this treatment.
4. It includes carbonate conditioning, colloidal conditioning, calgon conditioning, phosphate conditioning.

Difference between external & internal conditioning process of softening process.

(above the points 4 in external & internal conditioning write it)

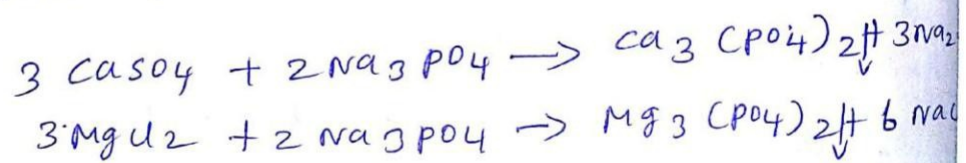
Internal conditioning process

a) colloidal conditioning

1. In low pressure boilers, scale formation can be avoided by adding organic substances (or) colloidal substances like kerosene, agar-agar, tannin, gelatin etc.
2. colloidal substances coated over the scale forming particles and convert into the loose precipitate called sludge.
3. It can be removed by blow down operation.

b) phosphate conditioning :- 1. In high pressure

1. scale formation can be avoided by adding sodium phosphate.
2. The phosphate reacts with Ca^{2+} and Mg^{2+} salts to give soft sludges of Ca & Mg phosphates

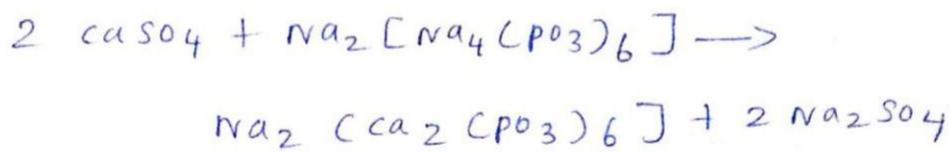


<u>No</u>	<u>name of phosphate salt</u>	<u>used in</u>
1.	Trisodium phosphate (Na_3PO_4)	acidic water
2.	Bisodium hydrogen phosphate Na_2HPO_4	weakly acid water
3.	Sodium dihydrogen phosphate $(\text{NaH}_2\text{PO}_4)$	Alkaline water

c) calgon conditioning

1. calgon is sodium hexa meta phosphate
 $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$

2. It reacts with Ca^{2+} to form highly soluble complex.
3. It prevents the precipitation of scale forming salt.
- calgon conditioning is better than phosphate conditioning



d) Sodium aluminate conditioning

1. Sodium aluminate reacts boiler water to give sodium hydroxide & gelatinous precipitate of *coagulant* aluminium hydroxide.



2. Sodium hydroxide reacts with Mg^{2+} ions to give magnesium hydroxide



3. Aluminium hydroxide & Magnesium hydroxide are produced inside the boiler.

4. Finely suspended & colloidal impurities, oil drops and silica formed.

5. It can be removed by pre-determined blow down operation.

external conditioning

Two methods

1. Demineralisation or ion-exchange process (or) deionisation process.
2. Zeolite (or) permutit process.

1. Demineralisation (or) ion-exchange process (or) deionisation process

Definition:

* Anions and cations are removed from the hard water is called de-ionisation process (or) demineralisation process.

* Soft water is not a demineralised water whereas demineralised water is a soft water.

* Demineralisation process, the ions present in water are removed by ion exchangers.

process

cation exchangers (or) cylinder-I

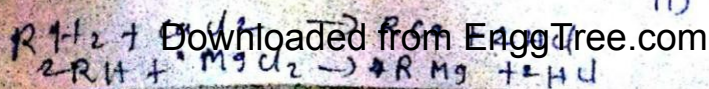
1. Hard water is passed through the I-cylinder absorbs all the cations like, Na^+ , K^+ , Mg^{2+} , Ca^{2+} called as cation exchangers

2. It is represented as RH_2 (or) RH

3. Examples: Sulphonated coal
Sulphonated polystyrene

4. Examples available UNIT 1 i) Amberlite IR-120 16

ii) Dowex-50



Ion-exchange (or) demineralisation process

Definition

* Removal of all ions (cations and anions) from the Hard water is called de-ionisation process (or) demineralisation process.

* Soft water is not a demineralised water whereas demineralised water is a soft water.

* Demineralisation process, the ions present in water are removed by ion-exchangers.

Resins are classified into two types.

1. cation exchange resin
2. Anion " "

Cation (or) Acidic exchange Resin (RH^+)

* It is containing acidic functional groups ($-COOH$, $-SO_3H$, etc).

* It exchange H^+ ions with other cations of hard water.

Example Sulphonated (or) carboxylated polystyrene

Role

* Hard water is passed through the cation resin. It removes all the cation like Ca^{2+} & Mg^{2+} .



Anion (or) Basic exchange Resins ($R'OH^-$)

* It is containing basic functional groups ($-OH$, $-NH_2$ etc).

* It exchange OH^- ions with other anions of hard water.

EX cross-linked polystyrene containing quaternary ammonium salts.

process

2. It Removes all the anions like SO_4^{2-} , Cl^- etc.



Finally

Regeneration

i) cation exchanger is regenerated by passing HCl or H_2SO_4 solution.



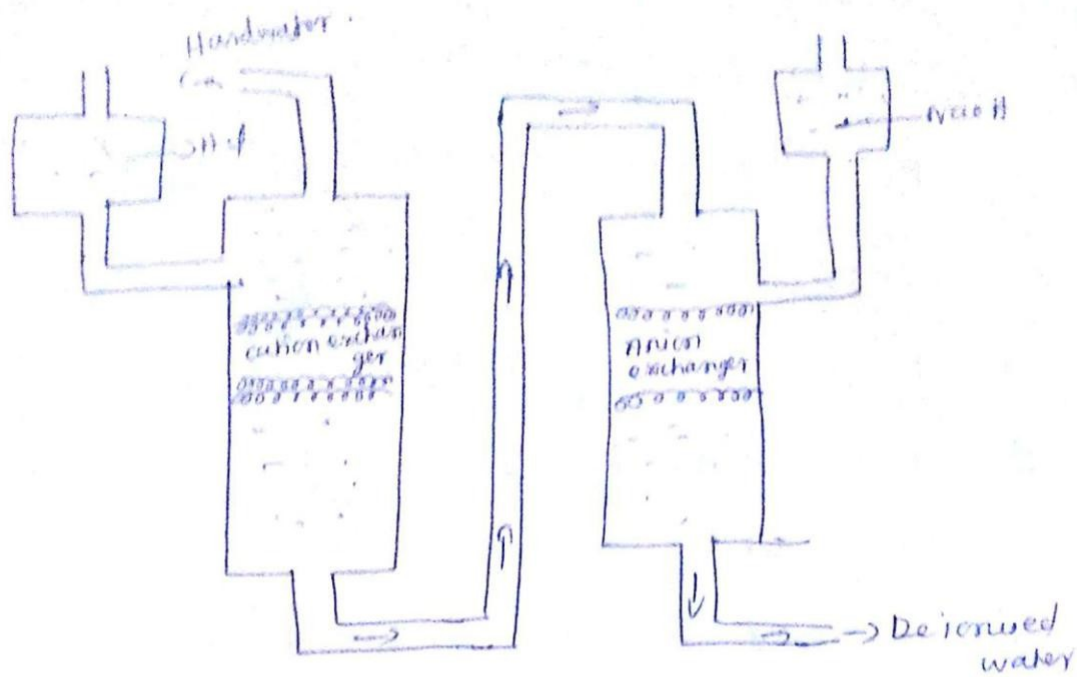
ii) Anion exchanger is regenerated by passing NaOH

Advantages

1. It is used to treat highly acidic or alkaline
2. It is used in high pressure boilers.
3. It produces water of very low hardness (up to 2 ppm)

Disadvantages

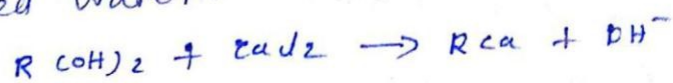
1. the equipment is costly.
2. Turbidity reduces the efficiency of the process.



Anion exchangers (or) cylinder - II

1. It absorbs the anions like Cl^- , HCO_3^- , SO_4^{2-} called as anion exchangers.
2. It is represented as R(OH)_2 (or) ROH
3. Examples: i) Urea formaldehyde resin
ii) Melamine Formaldehyde resin.
4. commercially available in i) Amberlite - 400
ii) Dowex - 3

completely free from anions and cations ^{in the} water are removed called as deionised water (or) demineralised water.

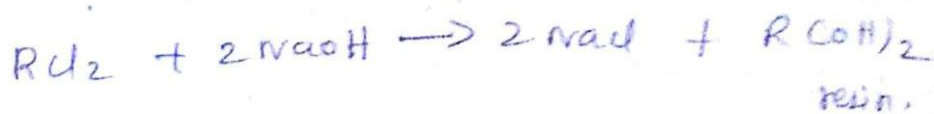


Regeneration

1. cylinder - I passed through the acid



2. cylinder - II passed through the base



Advantages

1. It is used to treat highly acidic or alkaline water.
2. It is used in high pressure boilers.

Disadvantages

1. It is costly and more expensive method.
2. Turbidity reduces the efficiency of the process.

Zeolite (or) permutit process

Definition: The process of removing hardness producing salts from ~~mineral~~ ^{zeolites} are also known as permutit by using zeolites is called Zeolite process.

* Zeolites are naturally occurring hydrated sodium aluminosilicate.

* general formula is $Na_2O \cdot Al_2O_3 \cdot xSiO_2 \cdot yH_2O$
($x = 2-10$, $y = 2-6$).

Types ∴ Two types

1. Natural zeolites: non-porous & green sand

Ex natrolite: $Na_2O \cdot Al_2O_3 \cdot 4SiO_2 \cdot 2H_2O$

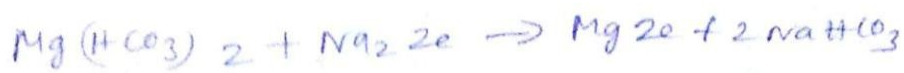
2. Synthetic zeolites: porous & gel structure

* Synthetic form of zeolite is known as permutit.

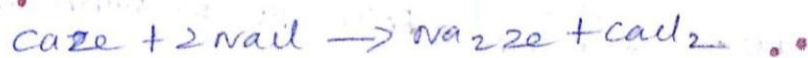
* It is represented by Na_2Z

Process

When hard water is passed through a bed of Sodium zeolite (Na_2Ze), and exchange the sodium ions with Ca^{2+} & Mg^{2+} to form Ca & Mg zeolites.

Regeneration

The exhausted zeolite is again regenerated by treating with 10% solution of NaCl. ^{(or) 10% brine solution.}

Advantages

- i) Hardness of water 1-2 ppm by this process water obtained.
- ii) It can be used again
- iii) No sludge is formed
- iv) It occupies a small space.
- v) It operates easily.

Disadvantages

- i) Blocks the pores of the zeolite bed - Turbid water.
- ii) Decomposes the structure of zeolite - Acidic water

- III) It produced resulting in boiler corrosion and caustic embrittlement.
- IV) Regeneration is very difficult.
- V) This process cannot be used for softening brackish water.
- VI) Turbid water & highly acidic water cannot be treated.

Differences between zeolite and demineralisation process

Zeolite process

1. It exchange only cations
2. Acidic water cannot be treated.
3. It produces priming & foaming
6. ~~Suitable~~ ^{foaming} for all types of boilers $\leq$
4. It can be used in high pressure boilers.
5. Hardness range 0-15 ppm
7. It occupies less space
7. portable water Treatment

Demineralisation process

- It exchange cations & anions
- Acidic water can be ^{s alkaline 1120} treated.
- no priming & foaming
- not suitable for high pressure boilers.
- It cannot be used in boilers.
- D-2 ft ppm. more space

Definition

water that is used for drinking purpose known as potable water.

Standards of drinking water

water used for drinking should be

1. colourless and odourless
2. free from any suspended or colloidal impurities
3. free from micro organisms and bacteria

untreated water contain pathogens, chemical pollutants and other component like odour, turbidity, algae etc.

Treatment method

1) Heating (or) boiling

- Heat kills disease causing micro organism.
- Boiling does not leave any residual protection.

2) Filtration

potable pump filters remove most bacteria & protozoa, But they do not kill viruses.

3) Activated charcoal adsorption

- It can remove chlorine from treated water.
- It protects water against pathogens.

4) Chemical disinfection

- chemical disinfection with Cl_2 & I_2 results from oxidation of cellular structures and enzymes.
- sodium dichloroisocyanurate (NaDCC) is used for water treatment.
- Iodine kills many common pathogens in fresh water sources.
- ozone finds use in municipal water treatment plants, food processing units and healthcare organisations.

5) ultra violet purification

In solar water disinfections (SODIS), microbes are destroyed by temperature and UV radiation provided by the sun.

vi) Solar distillation

These methods are commonly used at household level in developing countries, by recreational enthusiasts, military personnel, survivalists.

Desalination of brackish water

Definition

* The process of removing common salt (NaCl) from the water is known as desalination

* Water containing high concentration of dissolved salts is known as brackish water

Water quality based on dissolved salts as

1. Freshwater — contains < 1000 ppm of dissolved
2. Brackish water — " $1000 - 35000$ ppm "
3. Sea water — " > 35000 ppm "

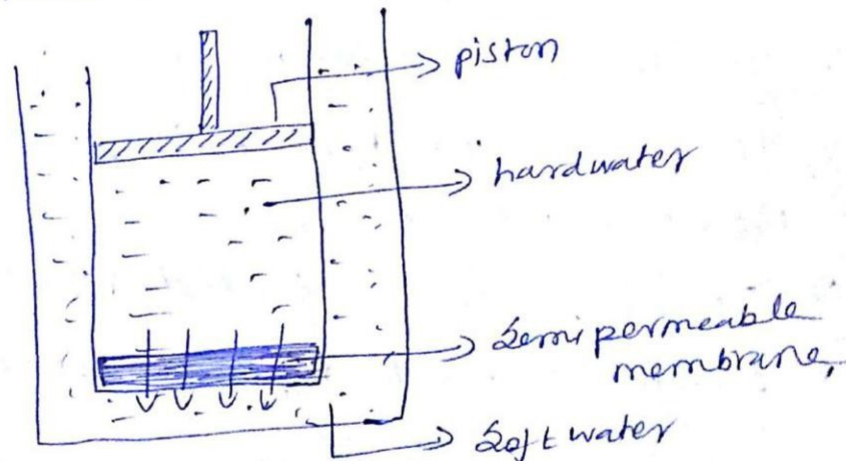
Some techniques are used for desalination of brackish water

- i) distillation
- ii) electrodialysis
- iii) reverse osmosis

Reverse osmosis process

principle :- osmosis

- * When two solutions are separated by a semi-permeable membrane, the solvent molecules will move from dilute solution to the concentrated solution.
- * This process is known as osmosis.
- * When a hydrostatic pressure applied on the concentrated side, solvent molecules move from concentrated solution to the dilute solution.
- * This process is known as Reverse osmosis.



process

- * In this method, hard water is taken in the inner vessel.
- * Soft water is taken in the outer vessel.
- * Hard & soft water are separated by semi permeable membrane.

- * A hydrostatic pressure applied on the hard water side.
- * The solvent molecules move from concentrated solution to dilute solution.
- * Thus softening of hard water takes place.
- * Sulphone, cellulose acetate, polyamide and polyacrylonitrile^{or} used as semi-permeable membranes.

Advantages

- * This process is used for purify the sea water for drinking purpose.
- * The life time of the membrane is high.
- * It removes all types of impurities (ionic, non-ionic, colloidal).
- * This process is used for high pressure boilers.
- * Membrane can be replaced within short time.
- * It is very less expensive method.

Up Flow ~~or~~ Anaerobic Sludge Blanket CUASB) process

principle

- * In this process waste water enters the reactor from the bottom & flows upward.
- * A suspended sludge blanket are filtered.

Process

- * UASB is a single tank process.
- * It uses a reactor.
- * Reactor are constructed using concrete (or) other water tight material.
- * It can be designed in a circular (or) rectangular.
- * Waste water is pumped from the bottom into the reactor.
- * Bacteria growth on the sludge.
- * A sludge blanket is comprised of microbial granules of 1 to 3 mm in diameter.
- * The microorganisms in the sludge layer degrade organic compounds
- * Gases like methane, CO_2 , biogas are released.
- * The rising bubbles mix the sludge.
- * Equilibrium forms a stable and suspended sludge blanket
- * The effluent is extracted from the top of the tank.
- * A gas - liquid - solid separator (GLSS) separates the gas from the treated waste water and the sludge

Advantages

- * Biogas are produced & used as energy source.
- * Sugars dissolved in the liquid waste stream converted into gas quickly.

- * High reduction in organics.
- * The nutrient rich effluent used as soil fertiliser after composting.

Dis advantages

- * Long start-up time.
- * constant source of electricity is required.
- * Difficult to maintain proper hydraulic condition
- * Requires expert design and construction super
- * Intake waste water streams with 3% total suspended solids (TSS) with particle size $< 0.75 \text{ mm}$

Boiler troubles ~~on~~ Boiler feed water ~~on~~ disadvantages

Definition of using hardwater in boiler

* water used in boilers to generate steam known as boiler feed water.

* Hard water is used in boilers many troubles will arise. They are

1. Scale & sludge formation
2. corrosion of the boiler metal
3. caustic embrittlement
4. Foaming & priming

1. Boiler Scale formation

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on heating continuously, the dissolved salts in water gets deposited as a coating

on the boiler surface. This is known as boiler scale.

Disadvantages of Boiler scale

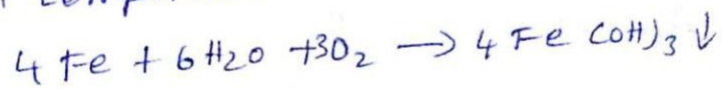
- i) Boiler scale is a bad conductor of heat, so the wastage of fuel.
- ii) The scales block the safety valves, the boiler explosion.
- iii) Corrodes the boiler metal
- iv) Boiler metal loses its strength

Corrosion of boiler metal

It is due to the presence of

- | | |
|-----------------------------|--------------------|
| a) dissolved oxygen | d) chemical |
| b) dissolved carbon dioxide | e) electrochemical |
| c) dissolved salts. | f) environment |
| | g) mineral acids |
| | h) |

- a) dissolved oxygen → It attacks the boiler metal at high temperature.



Remedies

Dissolved oxygen can be removed by chemical or mechanical methods by deaeration.

- b) Dissolved CO_2 → It produces carbonic acid which corrodes the metal.

Remedies

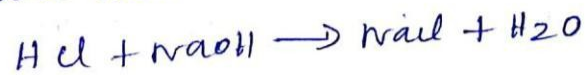
By removing CO_2 using lime

or by mechanical deaeration method

Mineral acids $\rightarrow$ It attacks the boiler metal and corrode it.

Remedies

By neutralising mineral acids with bases like soda ash.



caustic embrittlement Inter crystalline cracking

Definition

* Corrosion which occurs at the cracks and inside the boiler parts is called caustic embrittlement.
* This effect is due to the presence of sodium hydroxide in water.

* This problem can be avoided by using lime.



Prevention

It can be prevented by

- i) using sodium phosphate & sodium carbonate
- ii) by adding tannin, lignin to the boiler water

priming & foaming (carry over)

priming

Definition

* It is the process of production of wet steam.
* It is the rapid and violent boiling of H_2O .

It is caused by

- High steam velocity
- very high water level in the boiler
- Sudden boiling of water
- very poor design of the boiler

prevention

It can be controlled by

- control the velocity of steam
- Keep the water level lower.
- Good boiler design proper and uniform heating
- using treated water

foaming

Definition

* The formation of stable bubbles above the surface of water is called foaming.

* It is caused by

- presence of oil & grease
- presence of finely divided particles.

prevention

It can be prevented by

- adding coagulants like sodium aluminate aluminium hydroxide.
- adding anti-foaming agents like synthetic polyamides.

2 mark questions (Additional questions)

What are the methods used to prevent scale formation?

- ✓ Scraping & wire brush used.
- ✓ blow down operation.
- ✓ thermal shocks.
- ✓ adding chemicals

What are boiler compounds. Give two examples
Scale forming substances can be removed by adding chemicals directly to the boiler.

EX Na_2CO_3 , Na_3PO_4

3. What are the methods used to soften hard water
- i) External treatment - zeolite process, ion-exchange, Reverse osmosis
 - ii) Internal " - carbonate, colloidal, phosphate, sodium aluminate, calgon.

4. Mention the units used for expressing hardness of water?

- i) ppm ii) Mg/L iii) Clark's degree iv) French degree

5. What are ion exchange resins?

Ion-exchange resins are insoluble, long chain, cross-linked organic polymers which are permeable due to their micro porous structure

6. Name the salts responsible for scale and sludge.

Scale: $\text{Ca}(\text{HCO}_3)_2$, CaSO_4

Sludge: MgCO_3 , MgCl_2

7. What is blow-down operation?

It is process of removing a portion of concentrated water by freshwater frequently from the boiler during steam production.

treatment method

treatment

Heating

Filtration

Activated charcoal
adsorption

chemical disinfection

a) Sodium dichloro
isocyanurate

b) Iodine

c) Ozone

ultraviolet purification.

Solar distillation

used in

destroy the micro
organism

Remove bacteria &
protozoa.

prote.
destroy the
pathogen

purify the
water treatment

Kills the pathogen
on
drying

municipal water
treatment-
food processing units

destroyed the
microbes

purify the water

Unit - II Surface chemistry & catalysis

Definitions

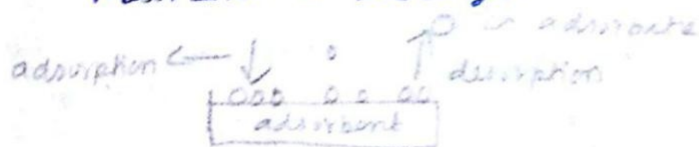
1. Adsorption

The phenomenon of accumulation of gas (or liquid) molecules on the surface than in the bulk of a solid or liquid is known as adsorption.

Example: Silica gel adsorbs moisture (from the dehydrator)

Adsorbate - moisture

Adsorbent - Silica gel.



2. occlusion

Adsorption of a gas on a solid is called occlusion.

Example Hydrogen gas adsorbed by metals like Ni, Pt, Pd etc.

3. adsorbent:

The solid surface on which a substance gets adsorbed is known as adsorbent.

Example charcoal, silica gel, metal like, Ni, Cu, Pt

4. Adsorbate

The substance that is adsorbed on the solid surface is known as adsorbate.

Example gases like O_2 , H_2 , Cl_2

5. Desorption

The process of removing an adsorbed substance from a surface is called as desorption.

6. Absorption

It is a process that a substance is uniformly

distributed throughout the bulk of the solid or liquid.
It is a bulk phenomenon.

7. Absorption

It is a process in which both adsorption & absorption occurs in a substance simultaneously.

Difference between adsorption & absorption

Adsorption

- 1- It is a surface phenomenon
2. It is a rapid process
3. Equilibrium is attained easily
4. It depends on the surface area of the adsorbent
5. The concentration of molecules are more on the surface area of the adsorbent

Absorption

It is a bulk phenomenon.
It is a slow process.
Equilibrium is attained slowly.

no such effect

The molecules are distributed uniformly

Classification of adsorption

It depends upon the kinds of forces operative in adsorption processes.

Two types

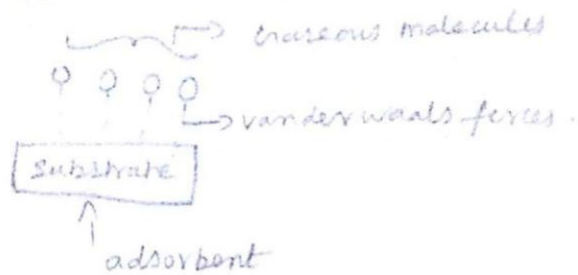
- 1- physical adsorption (or) physisorption (or) van der Waals adsorption
2. chemical " (or) chemisorption (or) activated adsorption

physical adsorption

Definition

When the force of attraction existing between adsorbate and adsorbent are weak van der Waals forces of attraction, the process is called physisorption.

Example : O_2 & H_2 adsorbed on charcoal

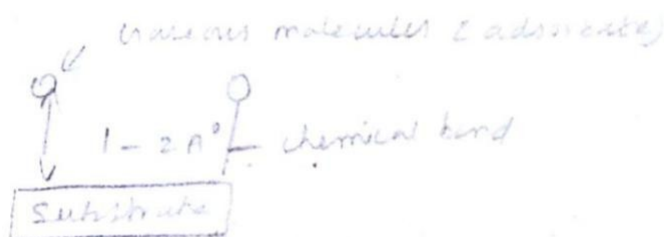


chemisorption :

Definition

When the forces of attraction existing between adsorbate and adsorbent are chemical forces of attraction (or) chemical bond (usually covalent bond). The process is called chemical adsorption.

Example Adsorption of H_2 on nickel



comparision of physisorption & chemisorption

physisorption

1. It is caused by weak inter molecular, vander waals forces
2. It is not specific in nature
3. Reversible in nature
4. It decreases with increases in temperature

chemisorption

- It is caused by strong, chemical bond formation
- It is highly specific
- Irreversible in nature
- It increases with temperature

- | | |
|--|--|
| 5. Adsorption is multilayer | only monolayer |
| 6. Heat low (30 kJ mol^{-1}) | Heat high ($40-400 \text{ kJ mol}^{-1}$) |
| 7. Equilibrium is established rapidly. | It requires more time |
| 8. It involves very small activation energy | It requires appreciable activation energy. |
| 9. The rate of adsorption increases with the increases of pressure and concentration | The rate of adsorption decreases with increase in pressure and concentration |
| 10. No surface compound is formed | Surface compound is formed. |
| 11. It is easy and fast process | It is difficult and slow process. |
| 12. <u>Ex</u> Adsorption of H_2 on charcoal | Adsorption of H_2 on Pt |

characteristics of adsorption

1. It is spontaneous process.
2. It takes place in no time
3. Heat is evolved during adsorption.
4. Decrease in free energy and entropy
5. It occurs in all surfaces.
6. It is a selective process
7. The rate of adsorption depends on Temperature
8. It depends on the nature of the adsorbent and adsorbate.

Ref.

Factors influencing adsorption (or) Factors affecting adsorption of gases on solids

1. nature of gases
2. pressure of gas
3. Temperature of gas
4. Activation of adsorbent
5. Thickness of adsorbed layer of gas
6. Reversible nature of adsorbed gas
7. Enthalpy of adsorption.
8. nature of adsorbents
9. Surface area of adsorbents

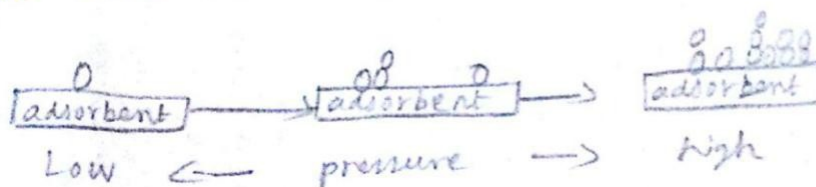
1. nature of gas (adsorbate)

× gases like NH_3 , Cl_2 , HCl , SO_2 etc which can be liquefied easily are more readily adsorbed on the solid surface rather than permanent gases like O_2 , H_2 etc.

× If the critical temperature of the gas is more, it will be adsorbed and liquefied more readily.

2. pressure of gas

• The Adsorption of gas increases with increase of pressure at constant temperature.



3. Temperature of gas

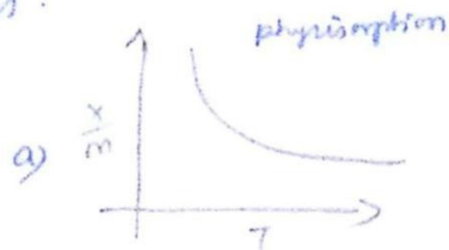
1. The Adsorption increases with decrease of temperature and 2. It is an exothermic process
3. Lower temperature favours adsorption

a) physisorption :-

It occurs rapidly at lower T and decreases with increasing T

b) chemisorption

It increases with increase in T and then decreases.



x = amount of adsorbate
 m = " " adsorbent

4. nature of adsorbent (solid)

1) Surface area increases and adsorption also increases.

Hydrogen $\rightarrow$ weakly adsorbed - on Alumina
 $\rightarrow$ highly " - on Ni

5. Thickness of adsorbed layer of gas

Physisorption $\rightarrow$ gas forms one molecule thick layer, at certain pressure multimolecular thick layer is formed.

Chemisorption $\rightarrow$ Adsorbed gas in one molecule thick chemical combination occurs with the adsorbent surface directly.

6. Enthalpy of adsorption

Physisorption $\rightarrow$ gas molecules and solid surface is due to weak Vander's waal's forces.

Heat of adsorption is small $\rightarrow$ about 5 kJ/mol

Chemisorption $\rightarrow$ Attractive forces are formed

chemical bonds.

Heat of adsorption is large / 100 K-cal / mol.

Reversible nature of adsorbed gases

physisorption $\rightarrow$ reversible process

$n_{\text{gas}} + \text{solid} \rightleftharpoons n_{\text{gas}} / \text{solid} + \text{heat}$

chemisorption $\rightarrow$ irreversible process because surface compound is formed.

nature of surface area of adsorbent

surface area increases and adsorption increases.

greater surface area $\rightarrow$ greater adsorption.

7. Activation of adsorbent

Activation leads to increase in the surface area of the adsorbent which increase adsorption.

Adsorption of solutes from solutions.

a) Adsorbents adsorb dissolved substances from solutions.

Example : Activated charcoal

- It adsorbs colouring matter present in sugar solutions
- It adsorbs out NH_3 from the solution of methyl orange

b) An adsorbent also adsorbs certain substances from the solution in preference to other substances.

- charcoal : It adsorbs non-electrolytes more readily than electrolytes from a solution.
- Alumina : It adsorbs electrolytes more readily than non-electrolytes from the solution.

Adsorption Isotherm

Definition

At constant temperature, there exists a relationship between the fractional coverage of the surface by the gas (θ) and pressure potential of the gas is known as adsorption isotherm.

$$\theta = \frac{\text{no. of adsorption sites occupied}}{\text{no. of adsorption sites available}}$$

Types of adsorption isotherms

* Brunauer has classified adsorption isotherms in five types.

* p_0 is the saturation pressure (equilibrium pressure)

Type I → It is typical Langmuir isotherm, when the adsorption is monolayer



Ex Adsorption of N_2 on charcoal at -188°

Type II → It represents a case of multilayer
* Adsorption increases with increase of p



Ex Adsorption of N_2 on Fe or Pt catalyst

Type III → physical adsorption on porous materials.



Ex Adsorption of Br_2 on silica or alumina at

Type IV → Adsorption on porous material accompanied by capillary condensation.



Ex Adsorption of benzene on silica gel at

Type V → physisorption on porous material accompanied by condensation.

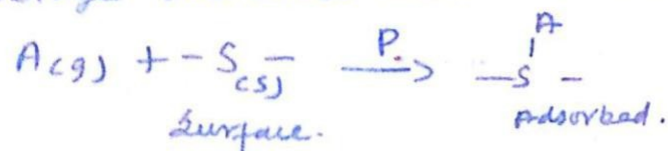


Ex Adsorption of water vapour on activated carbon at $100^\circ C$

Freundlich's Adsorption Isotherm

9

He proposed that the amount of gas adsorbed for a given quantity of adsorbent (substrate) increases rapidly with increase of pressure, but the rate decreases as the surface coverage increases more and more.



The empirical equation

$$x/m = k \times p^{1/n}$$

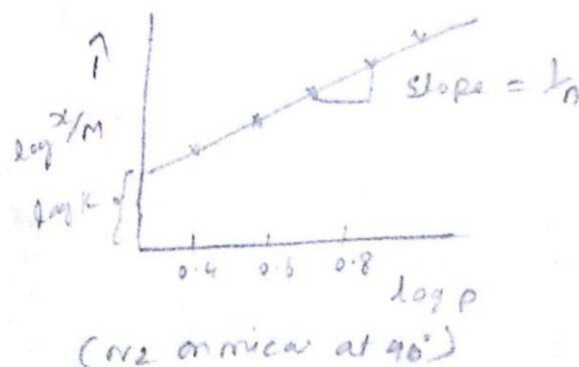
x = mass of the gas adsorbed

m = gram of the adsorbent

p = pressure

k & n = constants depend on the nature of solid & gas

Take log $\log \frac{x}{m} = \log k + \frac{1}{n} \log p$



The plot is a straight line at lower pressure, but deviates at high pressure.

(Significance where it) this place.

Limitations of Freundlich's Adsorption Isotherm

- i) Equation is purely empirical & has no theoretical basis.

- ii) It fails at high pressure
- iii) It fails when the concentration of adsorbate is very high.
- iv) The constants K and n are Temperature dependent.

Langmuir adsorption isotherm

Significance of Freundlich adsorption isotherm

- i) At low pressure $\frac{x}{m} \propto P$ or $\frac{x}{m} = K P^1$
- ii) At high pressure $\frac{x}{m} = \text{constant}$ or $\frac{x}{m} = K P^0$
- iii) At normal (intermediate) pressure $\frac{x}{m} \propto P^{\frac{1}{n}}$ or $\frac{x}{m} = K P^{\frac{1}{n}}$

Langmuir adsorption isotherm

- * H₂ theory of adsorption of a gas on the surface of a solid.
- * Relationship between the number of active sites of the surface undergoing adsorption and pressure.

Assumption or postulates

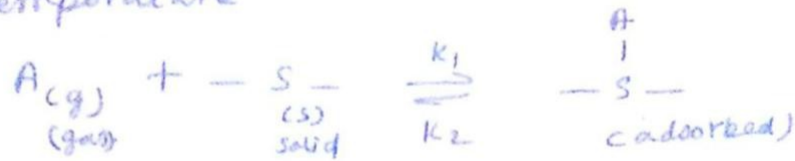
1. Fixed number of active sites.
2. Hold only one molecular or atomic species of the adsorbate.
3. Heat of adsorption is the same in all sites.
4. Solid is homogeneous, adsorbed layer is uniform.
5. no interaction takes place.

The relationship between the amount of gas adsorbed to the pressure of the gas at constant temperature is known as 'L-A' $x = x' \frac{K P}{1 + K P}$

6. Dynamic equilibrium between condensation (adsorption) and evaporation (desorption)
7. The adsorbed gas behaves ideally in the vapour phase.

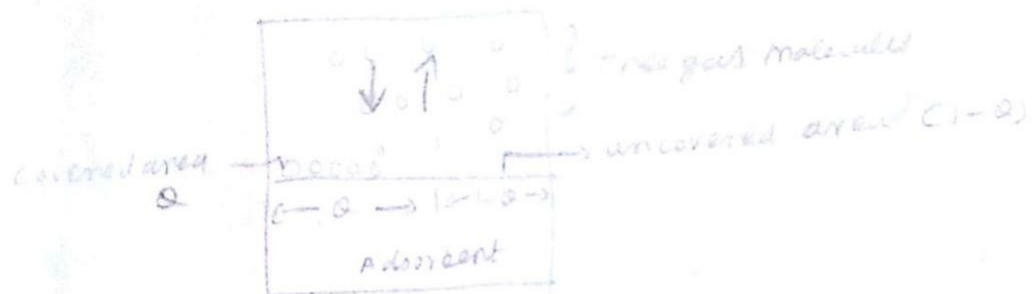
Process

* Consider an adsorption equilibrium process at a given temperature



* Rate of adsorption at a given instant $\propto$ pressure of gas and the area available for adsorption

$$\text{Rate} \propto P \times (1 - \theta)$$



$$\text{Rate of adsorption} = k_1 P (1 - \theta)$$

$$\text{Rate of desorption} = k_2 \theta$$

At equilibrium, rates are equal P_A is the equilibrium pressure

$$k_1 P_A (1 - \theta) = k_2 \theta$$

$$\therefore \frac{k_1}{k_2} P_A (1 - \theta) = \theta$$

$$\frac{k_1}{k_2} = K$$

$$K_{eq} P_A (1 - \theta) = \theta$$

$$K_{eq} P_A - K_{eq} P_A \theta - \theta = 0$$

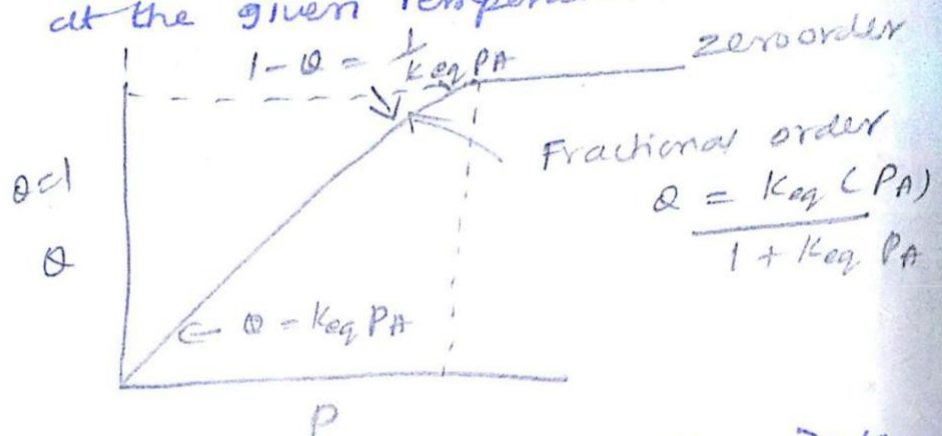
$$K_{eq} P_A - Q (K_{eq} P_A + 1) = 0$$

$$K_{eq} P_A = Q (1 + K_{eq} P_A)$$

$$Q = \frac{K_{eq} P_A}{1 + K_{eq} P_A}$$

$$= \left(\frac{k_1 P_A}{k_2 + k_1 P_A} \right)$$

Langmuir adsorption isotherm where P_A is the equilibrium pressure of the gas and K_{eq} equilibrium constant at the given Temperature



Significance of Langmuir adsorption isotherm

1. At low pressure $\rightarrow Q = K_{eq} P_A$
 $Q \propto P_A$ (first order)
2. At medium pressure $\rightarrow Q = \frac{K_{eq} P_A}{1 + K_{eq} P_A}$ (fractional order)
3. At very high pressure $\rightarrow K_{eq} P_A \gg 1$ (zero order)
Ex CO absorbed on charcoal

Demerits of Langmuir's Adsorption Isotherm

It has been found that Langmuir equation very often fails at high pressure.

Merits of Langmuir

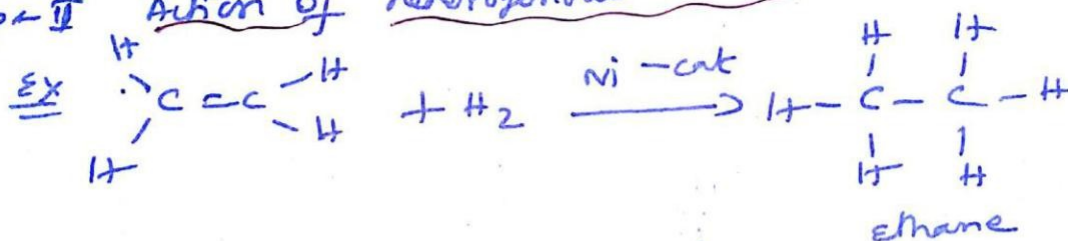
Langmuir adsorption holds good at lower pressure.

Adsorption on contact theory of catalysis

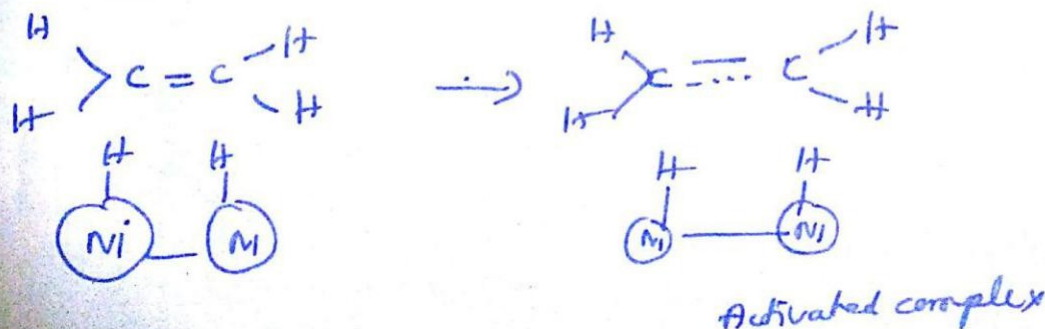
- * Theory was postulated by Faraday.
- * It explains the action of heterogeneous catalysis.

According to it: Step-I Adsorption of reactant molecules

1. The surface of the solid catalyst possesses some isolated active spots (or centres) having residual affinity of free unsatisfied valency force.
2. Due to these free unsatisfied valency forces on the catalyst

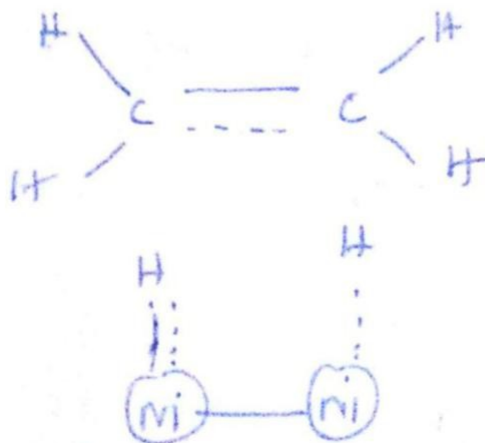
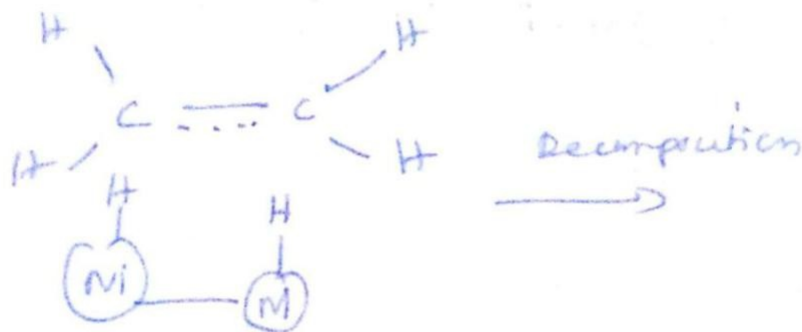
Step-II Action of heterogeneous catalystStep-III Formation of activated complex

This activated complex is unstable



Decomposition of Activated complex

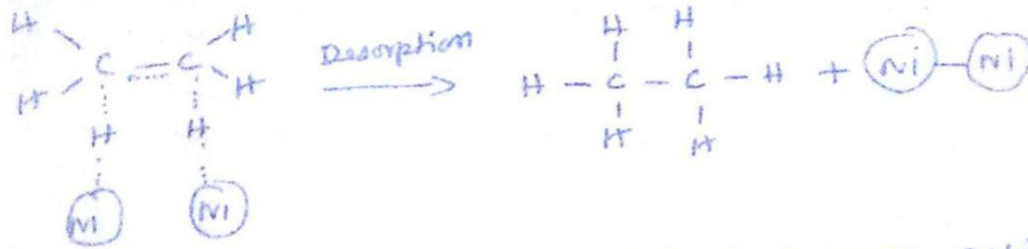
The activated complex breaks to form the products. The separated particles of the product are bound to the catalyst's surface by partial chemical bonds.



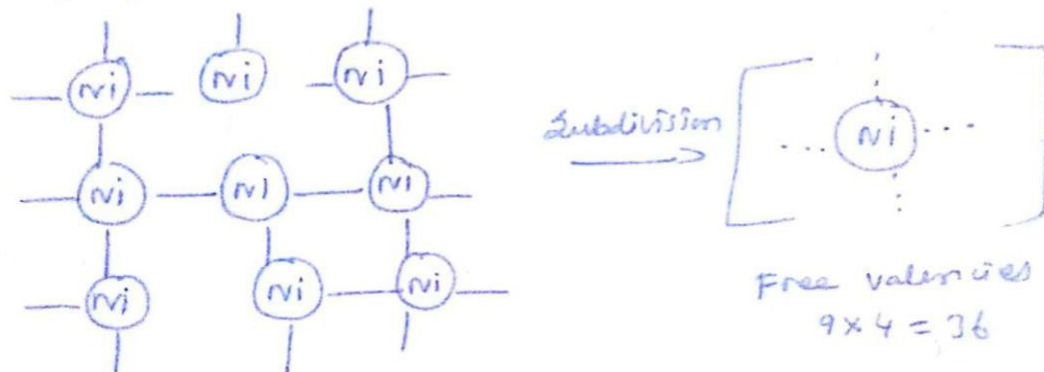
Step IV Desorption of products

15

The products are released from the surface

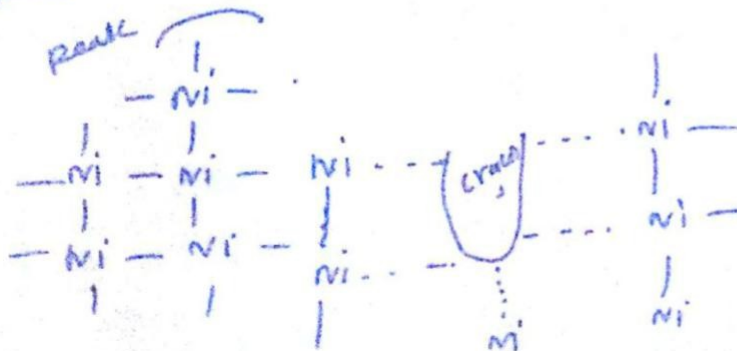


Finely divided state of catalyst is more efficient
 Catalyzed $\uparrow$ increases, the free surface area is
 $\uparrow$ increases & adsorption $\uparrow$ increases in free surface sides &
 activity of the catalyst is also enhanced.



Enhanced activity of a rough surfaced catalyst

Rough surface of a catalyst possesses "cracks"
 "peaks" "corners" etc

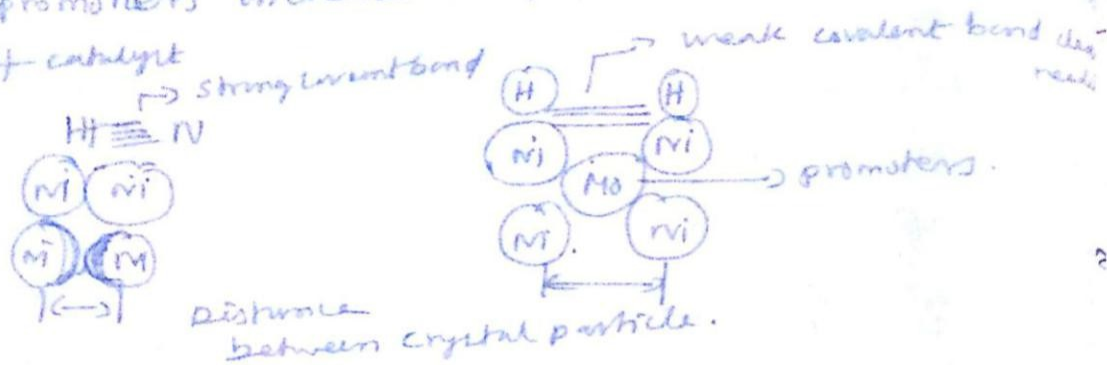


Action of promoters

Definition

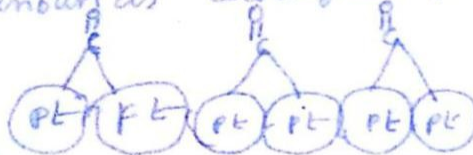
Promoters are defined as "the substances which increase the activity of a catalyst".

- 1) promoters change the lattice spacing between the catalyst particles.
- 2) promoters increase the peaks and cracks on the surface of catalyst



3 Action of catalytic poisons

Destroys the activity of a catalyst of the substance is known as catalytic poisoning. The rate of reaction decreases.



4. Specific action of the catalyst

- * The adsorption depends on the nature of both the adsorbent (catalyst) and the adsorbate (reactants).
- * The action of the catalyst is specific.

Kinetics of Surface Reactions

Types of Surface reactions

1. unimolecular reactions
2. Bi molecular "

Applications of adsorption on pollution abatement

17

Activated carbon is most commonly used adsorbent among the various adsorbents in pollution abatement of air and waste water, because it has a large surface area per unit weight or unit volume of solid.

Treatment of polluted water and air

Two types of activated carbons.

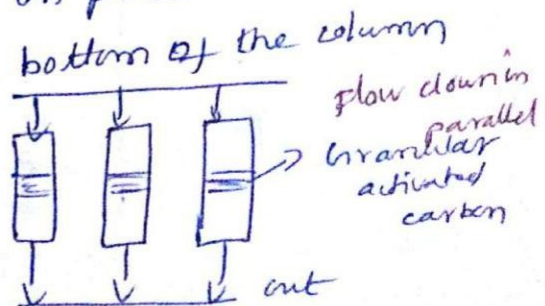
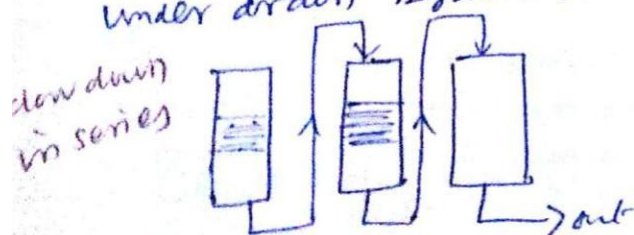
1. Granular Activated carbon (GAC)

- * A fixed-bed activated-carbon column is often used for contacting polluted water (or air) with GAC.
- * Series or parallel several types of fixed-bed activated carbon contactors are used in the treatment.

- a) Down flow fixed-bed carbon contactors
- b) up " fixed-bed " "

a) Down flow fixed carbon contactors.

- * It consist of 2 or 3 columns.
- * It operates in series or in parallel
- * The water (or air) is applied to the top of the column and withdrawn at the bottom.
- * The activated carbon is held in place with an under drain system at the bottom of the column.



unimolecular reactions

Examples of unimolecular reactions

- Decomposition of NH_3 to N_2 & H_2 on metal surfaces
- Decomposition of phosphine on glass
- Decomposition of N_2O on gold.

Mechanism

$$\text{Rate} = k_2 Q_A$$

As $k_2 \ll k_1$ $\therefore$ the rate of reaction of adsorbed molecules much greater than the rate of desorption of unreacted A.

$$\text{Rate} = k_2 Q_A = k_2 \frac{k_A P_A}{1 + k_A P_A}$$

Limitation of 1

a) At low pressure. $P_A \rightarrow 0$

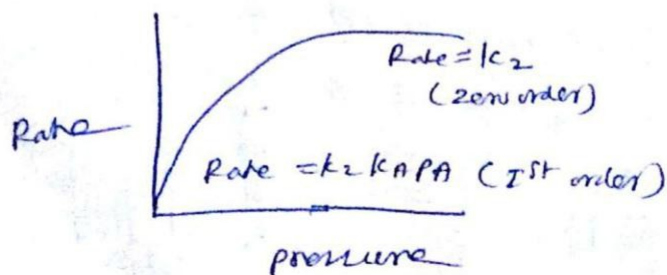
Q_A is very small and $1 + k_A P_A$ can be neglected

At low p rate = $k_2 K_A P_A$ $\therefore$ rate $\propto P_A$

b) At high pressure

$$\text{Rate} = k_2 Q_A = k_2 \frac{k_A P_A}{1 + k_A P_A} = k_2 \frac{k_A P_A}{k_A P_A} = k_2$$

$$K_A P_A \gg 1$$



Advantages

- * Adsorption of organic materials and filtration of suspended solids are accompanied in a single step.

Disadvantages

- * Decreasing the useful life of the carbon.
 - * Suspended material on the surface of the carbon.
- b) up flow fixed-bed carbon contactors
 up flow fixed-bed carbon contactors columns, the polluted water (or air) moves upward from the base of the column.

Advantages

As the carbon adsorbs organic materials, the density of the carbon particles increases and encourages migration of the behaviour or spent carbon downward.

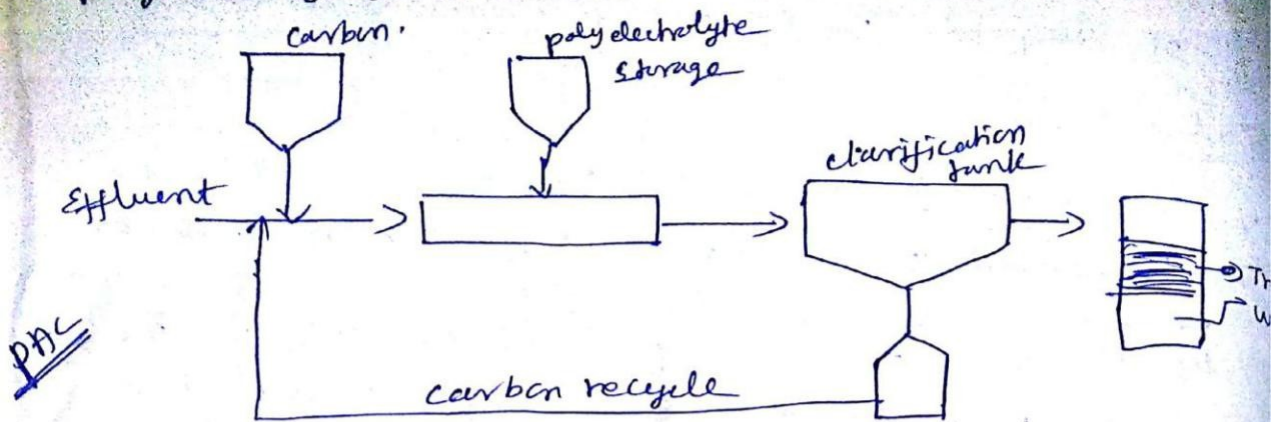
Disadvantages

- * up flow column may have more carbon fines in the effluent than down flow columns, because up flow tends to expand, not compress the carbon.
- * Bed expansion allows the fines to escape through passage ways created by the expanded bed

powdered Activated carbon (PAC)

- * In this method powdered activated carbon (PAC) is added directly into the effluent coming out from the various biological treatment processes.

✗ Biological treatment plant mixed with PAC and coag (poly electrolyte) in a contact - aeration tank.



- ✗ After some time the carbon particles get settled at the bottom of the tank
- ✗ poly electrolyte is added to removal of the carbon particles
- ✗ Regenerating column is used again and again.
- ✗ The water is filtered by filtration column.

Application of adsorption.

<u>Substance</u>	<u>used in adsorption</u>
1. Activated charcoal.	adsorb undesirable gases, decolouration in vinegar from the sugar solution
2. Silica & aluminagels	removing moisture
3. Heterogeneous catalysis	decompose the adsorption complex.
4. Fuller's earth	unwanted materials.
5. Ion-exchange resins	competing adsorption for softening of hard water.
6. Flath flotation process	sulphide ores (PbS, CuS)
7. Arsenic poisoning	arsenic poison removed from the body by vomiting
8. Lake test for Al^{3+}	Litmus colour by $AlCl_3$

7. Mordants

dyeing industry, adsorb colouring matter without attaching to the fabric.

8. production of high vacua.

all the gas molecules in the vessel.

9. chromatographic analysis

separating different pigments. & mixture of organic substances

10. Measurement of surface area

adsorption measurements.

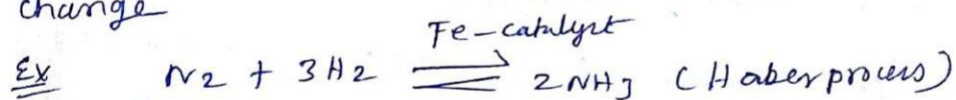
11. Evaporation of water is minimised

adsorption stearic acid

catalysis

catalyst — Definition

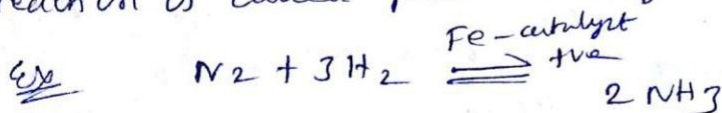
A catalyst is a substance which alters the rate of a chemical reaction without undergoing any chemical change



Types of catalyst

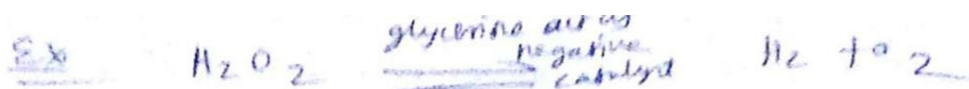
positive catalyst Definition

A substance which increases the rate of chemical reaction is called positive catalyst.



negative catalyst — Definition

A substance which decreases the rate of a chemical reaction is called negative catalyst



catalysis - Definition

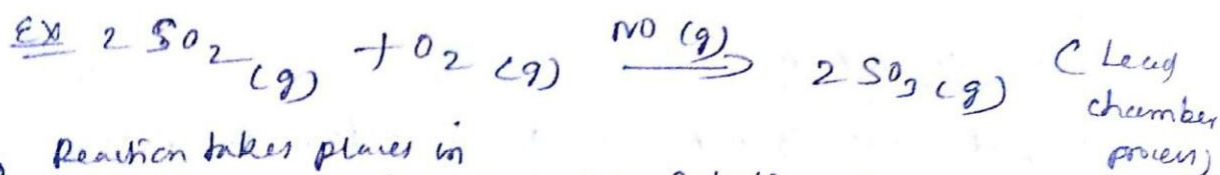
It is a process of altering the speed of a chemical reaction by adding suitable catalyst.

Types of catalysis

1. Homogenous catalysis
2. Heterogenous "

1. Homogenous catalysis - Definition

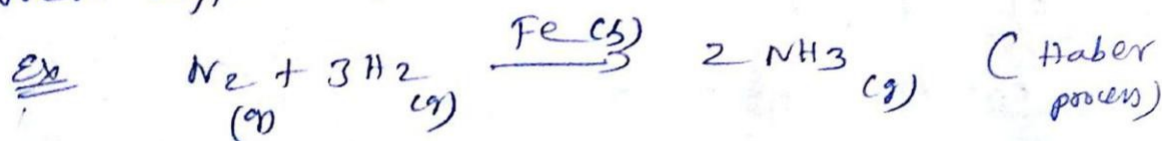
The process in which the catalyst and reactants are in same phase is called Homogenous catalysis.



2. Reaction takes place in mostly in the gas or solution phase.
3. Regeneration of catalyst is difficult.

2. Heterogenous catalysis - Definition

The process in which the catalyst and reactants are in different phase is called Heterogenous catalyst.



Reacting species - solid, gas & liquid } present in different phase
catalyst - solid.

This process is called contact catalysis.

Regenerated can be activated.

Ex: point

4. T increase the rate of the reaction

5. Reaction takes place in lower T & P chemical stability is low

Hetero
 T increases the rate of rxn,
Higher T & P
high.

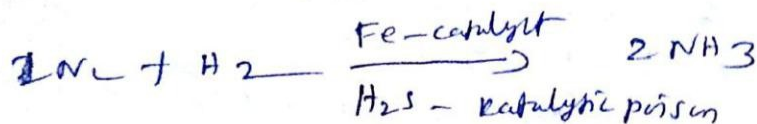
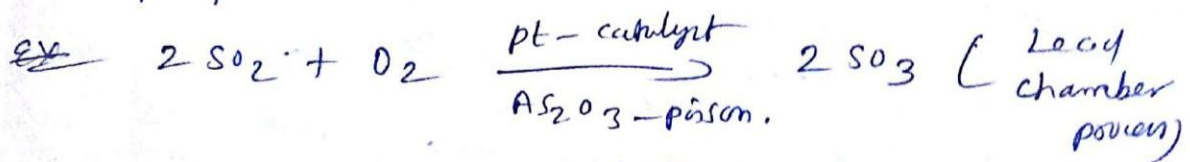
characteristics of catalyst (or) criteria of catalysis

(or) Features of catalysis

1. The catalyst remains unchanged in amount & chemical composition at the end of the reaction.
physical state may undergo change Ex colour, status, size
2. Only small amount of the catalyst is required.
3. The catalyst does not alter the position of equilibrium in a reversible reaction.
4. The catalyst is specific in its action.
5. Generally catalyst cannot initiate a reaction.
6. A catalyst is more effective, when it is finely divided.
7. A catalyst is more active at a particular temperature called the optimum temperature.
8. A catalyst is poisoned by certain substances.
9. The activity of a catalyst is enhanced by a promoter.

Catalytic poison - definition (or) Anti-catalyst

A substance which reduces or even destroys the activity of catalyst is called catalytic poison.

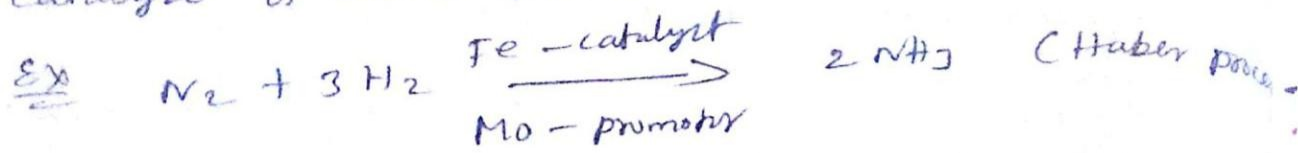


Types

1. Temporary poisoning
2. permanent "

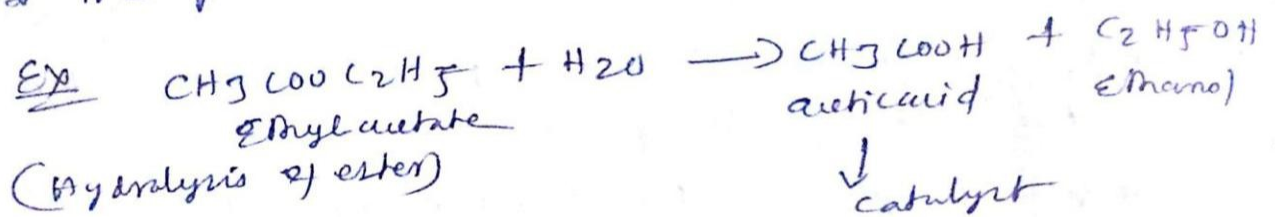
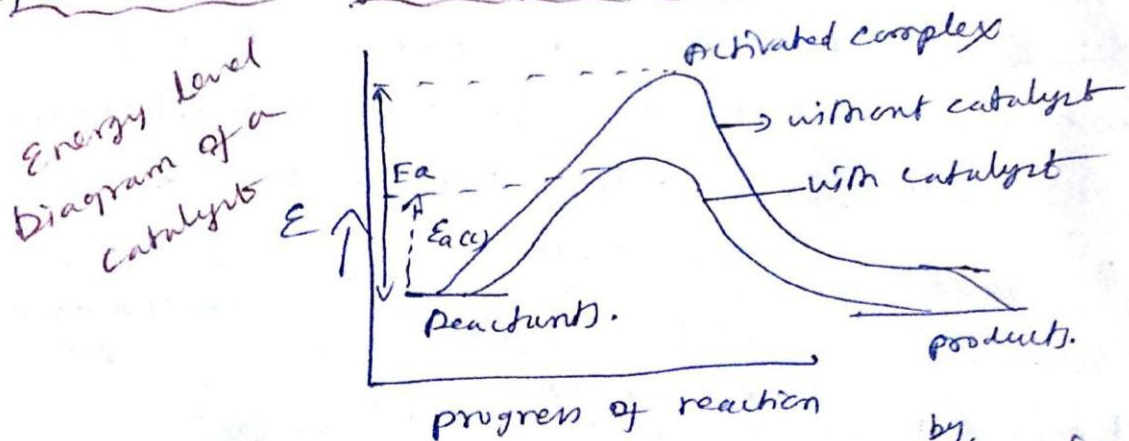
catalytic promotor - definition

A substance which increases the activity of catalyst is called promotor

Auto catalysis - definition

* When one of the products of a reaction itself acts as a catalyst for that reaction the catalyst is called auto catalysis

* The phenomenon is called auto-catalysis

function (or) effect of a catalyst

- * catalyst increases the rate of reaction by lowering energy E_a .
- * The activation energy (E_a) required for a reaction in the presence of a catalyst is small compared to that of reaction in absence of catalyst (E_a^*)

Acid - base catalysis

→ catalyst act as acid or base

→ Homogeneous catalytic reaction occurs in one liquid phase

Types of acid - base catalysis1. Types

1. Specific acid catalysis

2. General " "

3. Specific base " "

4. General " "

5. Acid-base " "

catalysed by

only H^+ or H_3O^+

Bronsted acid

only OH^-

Bronsted base

Bronsted acid is base.

Applications of catalystprocesscatalyst used →

1. Manufacture of NH_3 by

Haber process

→ Iron

2. Manufacture of H_2SO_4 by contact process → Pt

3. " " " chamber process → Nitric oxide

4. " " HNO_3 " Ostwald process → Pt

5. Hydrogenation of oils

→ Ni

6. Manufacture of H_2 from water gas → Ferric oxide

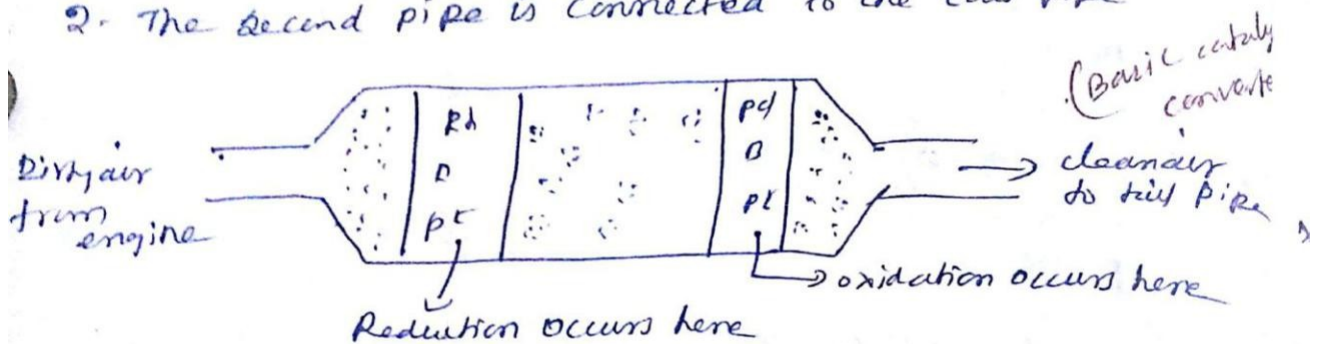
7. " " C_2H_5OH by fermentation method → Invertase, Zymase

catalytic converter

- A catalytic converter is a large an emissions device that converts toxic gases and pollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction.
- They use noble metals like Pt, Pd, Rh.

Construction

- A catalytic converter is a large metal box, bolted to underside of your car, that has two pipes coming out of it.
- 1. one pipe is connected to the engine & brings in hot polluted fumes from the engine's cylinders.
- 2. The second pipe is connected to the tail pipe.



Working

- Molecules of polluting gases from the engine are pumped over catalyst made from Pt, Rh, Pd.
- Catalyst splits up the molecules into their atoms.
- The atoms then recombine into molecules of relatively harmless substances such as CO_2 , N_2 & H_2O .

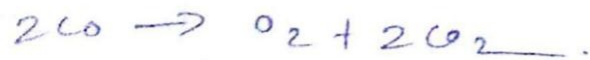
Functions

- car exhaust into more harmless molecules like CO_2 .

Three functions

- Reduction of NO_2 into N_2 & O_2
- $$2\text{NO}_2 \rightarrow \text{N}_2 + \text{O}_2$$

2. oxidation of CO to CO₂



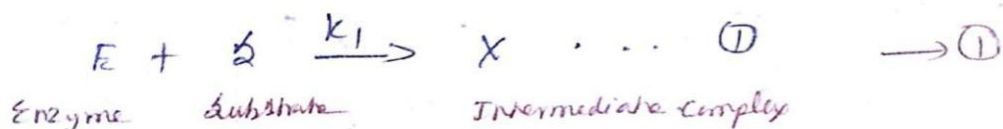
3. oxidation of hydrocarbons into CO₂ & H₂O



Michaelis-Menten equation (Enzyme Kinetics)

* Michaelis & Menten proposed the mechanism for enzyme catalysed reaction.

* Let Enzyme E react with the substrate S. The first stage is the formation of an intermediate complex X.



* dissociate to give E & S (or) final product P



$k_1, k_2, k_3 \Rightarrow$ rate constant

$$\begin{aligned} \frac{d[X]}{dt} &= k_1[E][S] - k_2[X] - k_3[X] \\ &= k_1[E][S] - (k_2 + k_3)[X] \quad \rightarrow \text{④} \end{aligned}$$

$[E], [S], [X] \Rightarrow$ molar concentrations.

The rate of formation of the product P

$$\frac{d(P)}{dt} = k_3[X] \quad \rightarrow \text{⑤}$$

$$[E_0] = [E] + [X]$$

equation (4) written as

$$\frac{d(x)}{dt} = k_1[E_0] - [x][S] - (k_2 + k_3)[x]$$

$$\left[\therefore [E] = [E_0] - [x] \right] \rightarrow (6)$$

E_0 = total concentration of the enzyme

Intermediate complex is unstable.

$$\frac{d(x)}{dt} = 0 \rightarrow (7)$$

This state is termed as the stationary state.

$$k_1 \{ [E_0] - [x] \} [S] = (k_2 + k_3) [x] \rightarrow (8)$$

$$k_1 [E_0] [S] - k_1 [x] [S] = (k_2 + k_3) [x]$$

$$k_1 [E_0] [S] = k_1 [x] [S] + (k_2 + k_3) [x]$$

$$k_1 [E_0] [S] = \{ k_1 [S] + (k_2 + k_3) \} [x]$$

$$(9) \quad [x] = \frac{k_1 [E_0] [S]}{k_1 [S] + k_2 + k_3} \rightarrow (9)$$

Dividing the eqn (9) by $k_1 [S]$

$$[x] = \frac{[E_0]}{1 + \frac{k_2 + k_3}{k_1 [S]}} \rightarrow (10)$$

Substituting the value of $[x]$ in equation 5 we get

$$\frac{d[P]}{dt} = \frac{k_3 [E_0]}{1 + \frac{k_2 + k_3}{k_1 [S]}} \rightarrow (11)$$

$$\frac{k_2 + k_3}{k_1} = K_m \text{ Michaelis constant}$$

Significance of Michaelis-Menten equation

In such a case, the rate will be maximum and no free enzyme will remain $[E_0] = [X]$

from equation 5

$$\frac{d[P]}{dt} = V_{max} = k_3 [E_0] \quad \rightarrow (15)$$

V_{max} = maximum

Michaelis-Menten equation can be written as

$$r = \frac{V_{max} [S]}{K_m + [S]} \quad \left[\because V_{max} = k_3 [E_0] \right]$$

If $K_m = [S]$

$$r = \frac{V_{max} [S]}{[S] + [S]} = \frac{V_{max} [S]}{2[S]}$$

$$\text{or } r = \frac{1}{2} V_{max}$$

Thus Michaelis constant is defined as "equal to concentration of substrate $[S]$ at which the rate of formation of product is half the maximum rate obtained at high concentration of the substrate."

Determination of Michaelis-Menten constant (K_m)

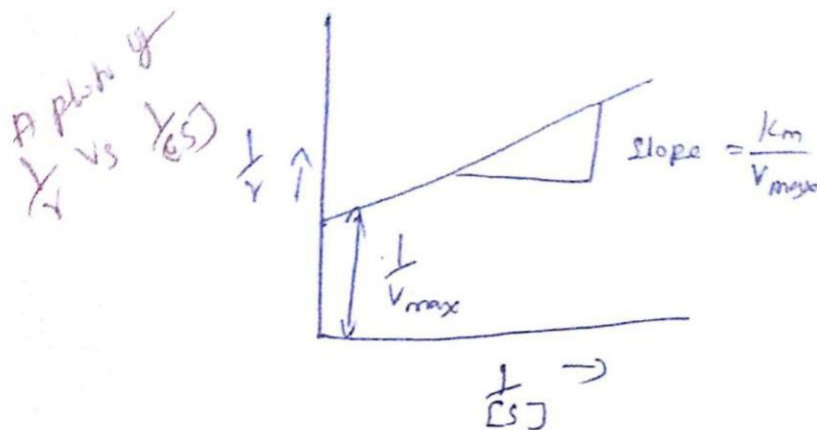
Lineweaver-Burk equation (or) Reciprocal of Michaelis-Menten equation

It is used to calculate Michaelis constant

$$\frac{1}{r} = \frac{1}{V_{max}} + \frac{K_m}{V_{max} [S]}$$

A plot of $\frac{1}{r}$ vs $\frac{1}{[S]}$ gives a straight line with intercept $\frac{1}{V_{max}}$ and slope k_m / V_{max} .

Michaelis-Menten's constant can be determined.



Turn over number (k_3)

It is defined as the number of molecules converted into products in unit time by one molecule of enzyme.

$$\frac{d[P]}{dt} = \frac{k_3 [E_0] [S]}{k_m}$$

This equation is known as turnover number.

Factors affecting enzyme catalysis

1. pH $\rightarrow$ neutral pH high or low pH (denature)
2. $\uparrow$ $\rightarrow$ in Enzyme reactions also increased.
3. Salt concentration $\rightarrow$ denaturation of enzymes.
4. Activators & inhibitors $\rightarrow$ increase or decrease the rate of reaction depends on the two nature.

unit - III - Alloys

Definition

It is a homogeneous mixture of two or more metals

Ex stainless steel, bray

properties of alloys / Significance of alloys

- * Alloys are harder and less malleable and possess lower melting points than their component metals.
- * Alloys possess low electrical conductivity
- * Alloys resist corrosion and the action of acids.

Significance (or) purpose of alloying

Alloys are prepared to get the following properties.

- i) To increase the hardness of the metal.
- ii) To improve machinability of the metals.
- iii) To improve malleability and ductility of the metals.
- iv) To improve abrasion resistance
- v) To get good corrosion resistance
- vi) To get metallic luster and attractive appearance.

Functions (or) effect of Alloying Elements

<u>element</u>	<u>Effect on properties</u>	<u>use of alloys.</u>
Nickel	i) improves tensile strength ii) increases corrosion resistance iii) produces fine grains	For making balance wheels
Chromium	i) Enhances tensile strength ii) High corrosion resistance iii) Improves hardness & toughness simultaneously	For making surgical instruments, cutlery, connecting rods etc

Vanadium	i) High abrasion & shock resistance ii) produces reversible stress	For making axles, crank pins, piston
Manganese	i) increase strength toughness & brittleness	For making grinding wheel, steering spindles
Molybdenum	i) increases both corrosion and abrasion resistance	For making high speed tools
Tungsten	i) increases abrasion and shock resistance ii) Enhances magnetic retentivity	For making cutting tools, permanent magnets

Nichrome

* It is an alloy of nickel and chromium.

	<u>Metal</u>	<u>%</u>
Nickel	(Ni)	60
Chromium	(Cr)	12
Iron	(Fe)	26
Manganese	(Mn)	2

properties

- * High melting point 1400°C
- * High electrical resistance $1.5 \times 10^{-6} \Omega \text{m}$
- * good resistance to oxidation and heat
- * used at 1000 to 1100°C
- * Ni & Cr stand T as high at 900°C

uses

- * electric irons
- * household electrical appliances
- * making parts of boilers, annealing boxes
- * " other machineries (or) equipments

Stainless steels (or) corrosion resistant steels

* chromium combine other elements, such as Ni, Mo etc.

Types of stainless steels

1. Heat treatable stainless steels
2. non heat " " "

Heat treatable stainless steels

a) composition $\rightarrow$ C $\Rightarrow$ 1.2%
Cr $\Rightarrow$ 12-16%

properties

* Magnetic, tough & can be worked as in cold condition

uses

- * used upto 800°C
- * good resistant weather & water
- * making surgical instruments

non-Heat treatable stainless steels

- * It possess less strength at high T
- * more resistant

Types

1. Magnetic type

composition

12-22% Cr
0.3% C

uses

making
chemical
equipment

2. non-magnetic type

18-26% Cr

8-21% Ni

0.15% C

Cr & Ni more than
23%

making
household
utensils,

Heat treatment of alloys

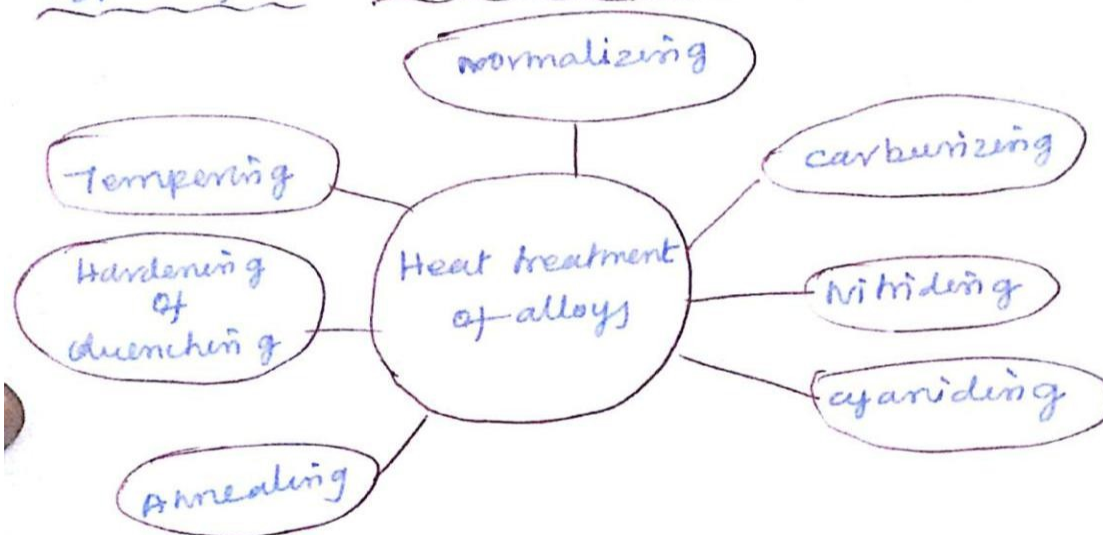
Definition

The process of heating and cooling of metals or alloys under controlled conditions.

Purpose (or) objectives of Heat treatment

- ✗ To remove internal stresses
- ✗ To refine grain structure
- ✗ To improve imprisoned trapped gases
- ✗ To improve magnetic & electrical properties

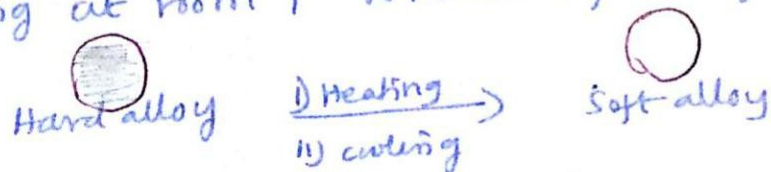
Types of Heat treatment of Alloys (Steel)



1) Annealing

Definition

It is a process involving heating and then cooling at room T to make softening



Purpose

- ✗ Increase machinability & internal stresses

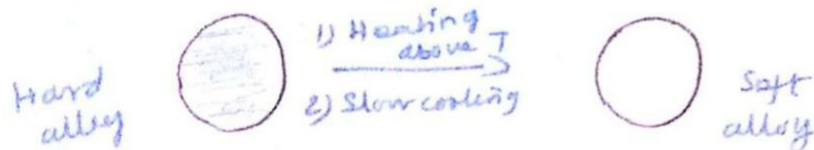
Types

- a) High temperature annealing (or) Full ann
- b) Low temperature " (or) process

1) High Temperature Annealing

Definition

It is a softening process in which a steel is heated to a temperature about 30°C to 50°C above the higher critical T and after holding it, at that T for a sufficient time is cooled slowly to room T .

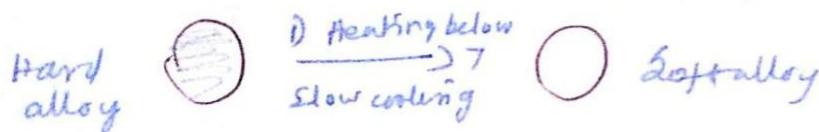


purpose : increase the ductility & toughness

2) Low Temperature Annealing

Definition

It is a softening process in which a steel is heated to a T below the lower critical T_L followed by slow cooling.

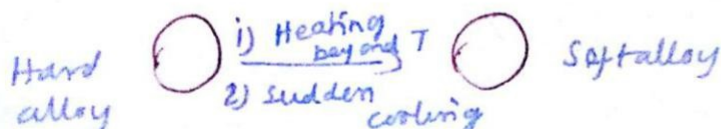


purpose : increases the ductility & shock resistance

3) Hardening (or) Quenching

Definition

It is a process of heating steel beyond critical T_L and then suddenly cooling it either in oil or brine water (or acid solution) or some other fluid.

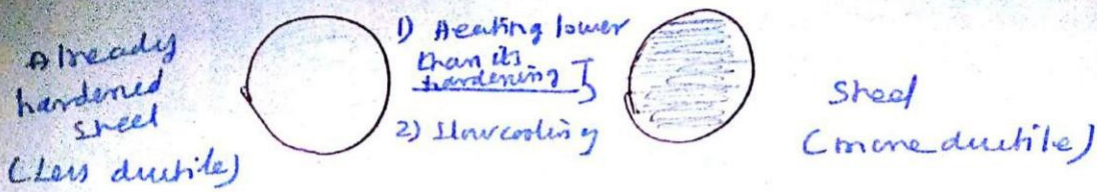


purpose : increases abrasion-resistance & resistance to wear

4) Tempering - definition

It is the process of heating the already

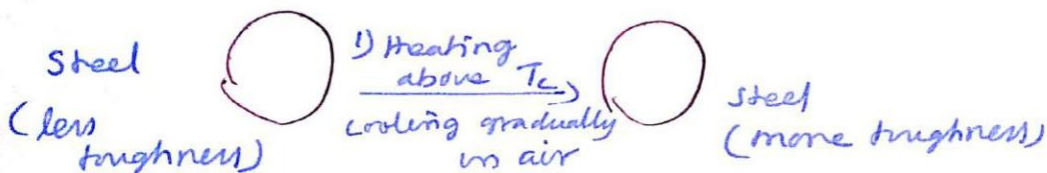
Hardened steel to a Temperature lower than its own hardening temp., and then cooling it slowly.



Purposes : Increases the toughness & ductility
Remove any stress & strains

Normalizing Definition

It is the process of heating steel to a definite temperature (above its higher critical T_c) & allow it to cool gradually in air

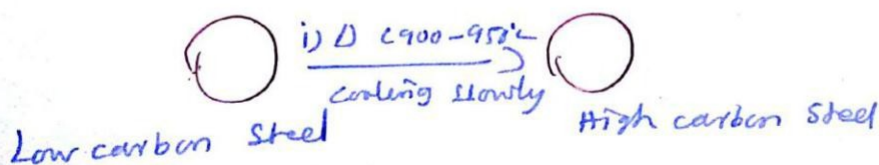


Purpose

- ✦ increase toughness
- ✦ removes internal stresses
- ✦ refines grains

Carburizing Definition

It is the process of increasing carbon content at the surface layer of low carbon content steel.



Purpose : To produce hard-wearing surface on steel article

6. nitriding Definition

* It is a process of hardening the surface of steel alloys.

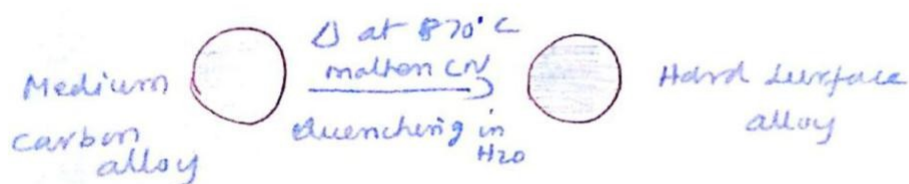
* In this operation, the steel alloy is heated in presence of NH_3 at a 750°C .



purpose: To get super-hard surface

cyaniding definition

" It is process of hardening the surface of medium carbon alloys."



18/8 Stainless steel or Allegheny Metal

<u>Metal</u>	<u>composition %</u>
Chromium	18 - 20 %
Nickel	8 - 21 %
Carbon	0 - 15 %

* It is the most used in ^{stainless} steel.

* Cr - 18 & C - 8%. Hence it's called 18/8 stainless steel.

properties

* maximum resistance to oxidation

* corrosion resistance increased by adding a little quantity of molybdenum.

uses making in

✶ household utensils

✶ sinks

✶ dental instruments

✶ surgical "

✶ medium acid & alkali plants

✶ " " refining units in petroleum

phase rule (or) Gibbs's phase ruleDefinition

When the equilibrium between any number of phases is influenced by pressure, temperature & concentration only, then the number of degree of freedom (F) of the system is related to number of components (C) and number of phases (P) by Gibbs's phase rule equation as

$$F = C - P + 2$$

Explanation of terms with examples1) phase (P)Definition

Any homogeneous physically distinct and mechanically separable portion of a system which is separated by definite boundaries from other parts of the system is called phase.

Examples

Gaseous phase $\rightarrow N_2, O_2, CO_2, H_2$
 Liquid " $\rightarrow$ benzene - water
 Solid " $\rightarrow$ Decomposition of $CaCO_3$

component (C)Definition

the minimum number of molecular species in terms of which the composition of all phases may be expressed quantitatively is known as component.

Examples

Water system
 $Ice_{(s)} \rightleftharpoons water_{(l)} \rightleftharpoons steam_{(g)}$

3. Degree of Freedom (F)

Definition

The minimum number of independent thermodynamic variable such as T & P at composition which must be fixed in order to define the system completely is known as degree of freedom.

Example

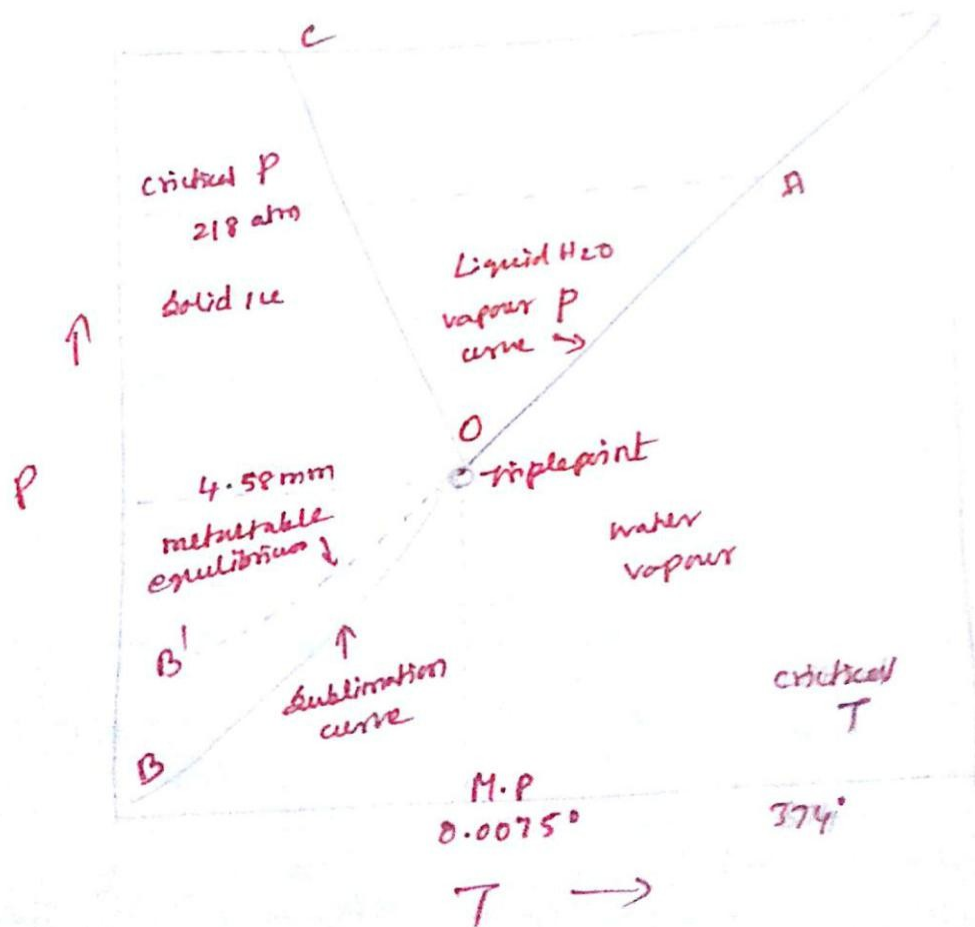
consider ice (s) $\rightleftharpoons$ water (l) degree of freedom

Applications of phase rule

one component system

water system

phase diagram of water system



Three phasessolid $\rightarrow$ iceliquid $\rightarrow$ watergas $\rightarrow$ steamThree equilibriasolid $\rightleftharpoons$ liquidliquid $\rightleftharpoons$ vapoursolid $\rightleftharpoons$ vapourPhase diagram1) three curves $\rightarrow$ OA, OB & OC2) " areas $\rightarrow$ AOC, BOC, AOB3) three or triple point $\rightarrow$ O4) metastable $\rightarrow$ equilibrium1) curve OA

i) It is called vapourisation curve

ii) water $\rightleftharpoons$ vapouriii) phase rule $F = C - P + 2 = 1 - 2 + 2 = 1$
(univariant)iv) critical T_c 374°C 2) curve OB

1) It is called sublimation curve

2) ice $\rightleftharpoons$ vapour3) phase rule $F = C - P + 2 = 1 - 2 + 2 = 1$ 4) Absolute T (OK or -273°C)3) curve OC

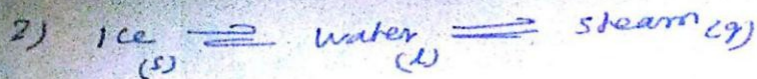
1) It is called melting point curve.

2) ice $\rightleftharpoons$ water3) phase rule $F = C - P + 2 = 1 - 2 + 2 = 1$

4) ice decreases, increasing pressure

4. Triple point

1) Three curves OA, OB & OC meet at a point 'O'. It is this point is called triple point.



3) phase rule $F = C - P + 2 = 1 - 3 + 2 = 0$

4. Degree of freedom is zero point 0.0075°C & 4 mm Hg

5. Areas AOC, BOC & AOB

AOC $\rightarrow$ water

BOC $\rightarrow$ ice

AOB $\rightarrow$ vapour

phase rule $F = C - P + 2 = 1 - 1 + 2 = 2$ (biv)

6. curve OB (Metastable equilibrium)

1) OB is called the vapour pressure curve of the supercool water or metastable equilibrium

2) $\text{supercool water} \rightleftharpoons \text{vapour}$

Two component Alloy system

Reduced phase rule (or condensed phase rule)

phase rule equation is

$$F = C - P + 2$$

Two component system ($C=2$) the degree of freedom

will be $F = 2 - P + 2 = 4 - P$

the system exists in a single phase $P=1$

$$F = 4 - P = 4 - 1 = 3$$

degree of freedom will be 3.

- * In order to represent the conditions of equilibrium graphically, it requires three co-ordinates namely P , T & composition (C).
 - * Three dimensional diagram cannot be represented as a paper.
 - * Any 2 or 3 variables must be taken for graphical representation.
 - * A Solid-Liquid equilibrium of an alloy system has practically no gaseous phase.
 - * Hence the effect of pressure is negligible.
 - * So the experiments are conducted under atmospheric pressure.
 - * Solid-Liquid equilibrium system, the gas phase is ignored and is called a condensed system.
- phase rule $F = C - P + 1$
- * pressure is kept constant.
 - * This equation is called reduced phase rule or condensed phase rule.

Types of two component system

- | | <u>Example</u> |
|---|------------------------------|
| 1. Simple eutectic formation | Lead-Silver, Bismuth-Cadmium |
| 2 a) Formation of compound with congruent melting point | → Zinc-Mg, Sn-Mg |
| b) Formation of compound with incongruent melting points. | → K-Na |
| 3. Formation of solid solution | → Cu-Ni |

Eutectic (or) easy meltDefinition

* A two component system contains two substances.

* They are completely miscible in the liquid state but immiscible in the solid state.

* This is known as eutectic.

Eutectic mixtureDefinition

Among the different mixture of two miscible liquid state and immiscible solid state the mixture having the lowest melting point is known as eutectic mixture.

Thermal analysis (or) cooling curve

* It analysis of two methods

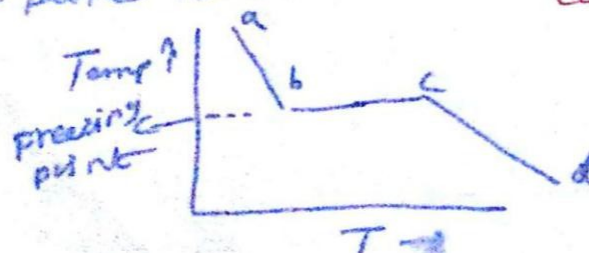
1. Thermo gravimetric analysis (TGA)

2. differential thermal " (DTA)

* The data obtained from thermal analysis along with recorded curves are known as thermogram or thermal spectra.

* cooling curves (or) Temperature curves of some simple systems discussed.

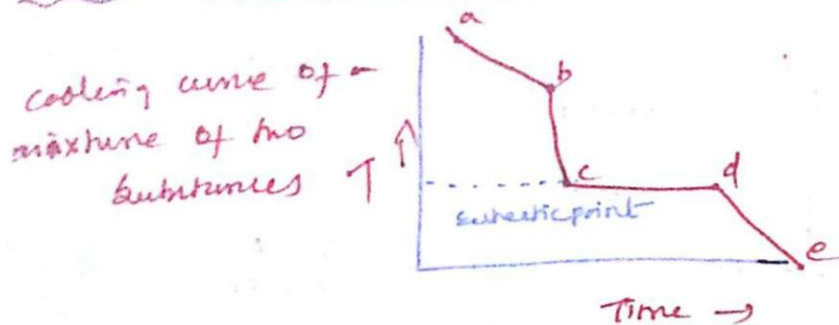
Ex A pure substance



cooling curve of a pure substance diagram

- The rate of cooling is continuous
- | | | | | |
|----|----|---------|---|------------------------------------|
| ma | ab | denotes | → | melted liquid |
| " | b | " | → | Freezing point |
| " | bc | " | → | T constant becomes solid |
| " | bc | " | → | equilibrium between solid & liquid |
| " | cd | " | → | T of the solid begins to decrease |

Example mixture of two substances



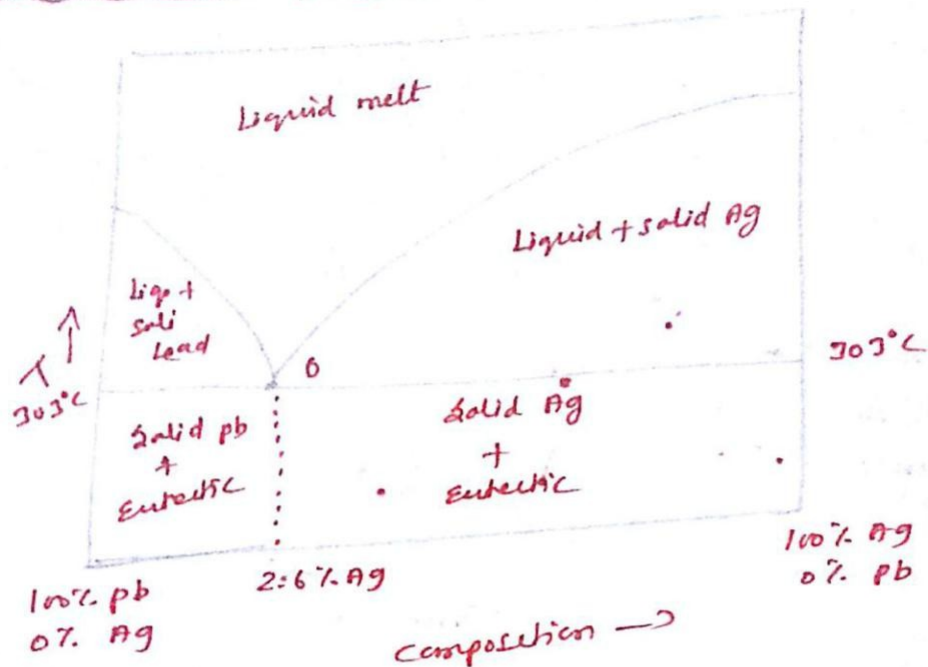
- * Two substance A & B melted liquid is cooled slowly.
- * The rate of cooling is continuous
- * Some substances begins to solidify out of the melt
- * This is indicated by a break.
- * This system becomes mono variant
- * Phase rule $F = C - P + 1 = 2 - 2 + 1 = 3 - 2 = 1$
- * T remains constant ^{until} the liquid melt is completely solidified.
- * This forms the eutectic mixture along cd.
- * Eutectic mixture has 3 phases (two solids & a liquid) the eutectic point is zero variant $C F = C - P + 1 = 2 - 3 + 1 = 0$

uses of cooling curves

- * It can be determined the Freezing point & eutectic T
- * purity of the system can be determined.
- * It can be studied the nature of the compound behaviour
- * The composition of alloys can be obtained from cooling curves.

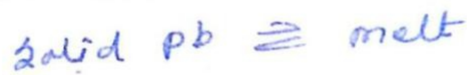
Simple Eutectic system

Lead - Silver System



i) curve BO

- * BO is known as the freezing point curve of
- * BO shows decrease the M.P of Pb



phase rule $F = C - P + 1 = 2 - 2 + 1 = 1$ univariant

ii) curve AO

- * It is known as the freezing point curve of
- * AO shows decrease the M.P of Ag



phase rule $F = C - P + 1 = 2 - 2 + 1 = 1$ monovariant

3. Eutectic point O

- * The curves AO & BO meet at point O at a T
- * Eutectic T)

At this point three phases (solid pb, Ag and their liquid) are in equilibrium.



phase rule $F = C - P + 1 = 2 - 3 + 1 = 0$ (reduced phase rule)

* The point O is called eutectic point

$T = 303^\circ\text{C}$ composition Ag $\rightarrow 2.61$
pb $\rightarrow 97.4$

* Below this eutectic point the eutectic mixture and the metal melt.

4. Areas AOB

* using reduced phase rule

$$F = C - P + 1 = 2 - 1 + 1 = 2 \quad \text{bivariant}$$

* AO represents $\rightarrow$ solid Ag + melt

BO " $\rightarrow$ solid pb + "

* area below point O $\rightarrow$ Eutectic compound + solid pb & Ag.

using reduced phase rule

$$F = C - P + 1 = 2 - 2 + 1 = 1 \quad \text{univariant}$$

Pattinson's process

(or)
Desilverisation of argentiferous lead

* The argentiferous lead has only 0.1% Ag.

* It is considered to be the ore of Ag.

* The ore is heated to be T above its M.P.

* It is represented by the point P. S cooled.

- * The T falls along the line pq.
- * q point is reached, ^(lead) pb is crystallised out.
- * More so, more ^(lead) pb is separated along the line Bo.
- * Melts continuously & reach the point O.
- * % of Ag rises to 2.6%.
- * % of Ag in the argentiferous lead is considerably (26 times) increases.

uses of eutectic mixture (or) system

- * prepare the alloys
- * join metal pieces
- * It is used in the formation of eutectic mixture
- * used in safety devices; fire sprinkles.

notes on

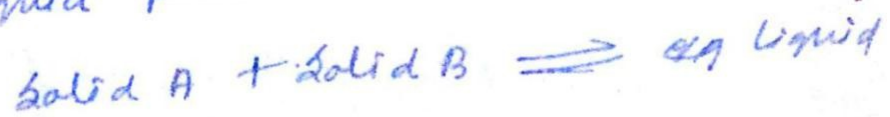
Melting point

It is the temperature at which the solid & liquid phases, having the same composition, are in equilibrium



Eutectic point

It is the temperature at which two solids and a liquid phase are in equilibrium



Triple point

It is the temperature at which three phases are in equilibrium.

Solid $\rightleftharpoons$ Liquid $\rightleftharpoons$ vapour

11

- i) All the eutectic points are melting points, but all the m-p need not be eutectic points.
- ii) All the eutectic points are triple points, but all the triple points need not be eutectic points.

Uses of phase rule

- * It is applicable to both physical & chemical equilibria.
- * convenient method to identify equilibrium states in terms of P, L & F
- * different systems having the same degree of freedom.
- * given number of substances remain in equilibrium or not

Limitation of phase rule

- * It is applicable only in equilibrium systems.
- * not considerable in electrical, magnetic & gravitational forces.
- * All the phase of the system must be present under the same conditions of P & T
- * Solid & liquid phases must not be in finely divided state, otherwise deviations occur.

unit - IV Fuels & CombustionFuelsDefinition

Any source of heat energy is known as fuel.

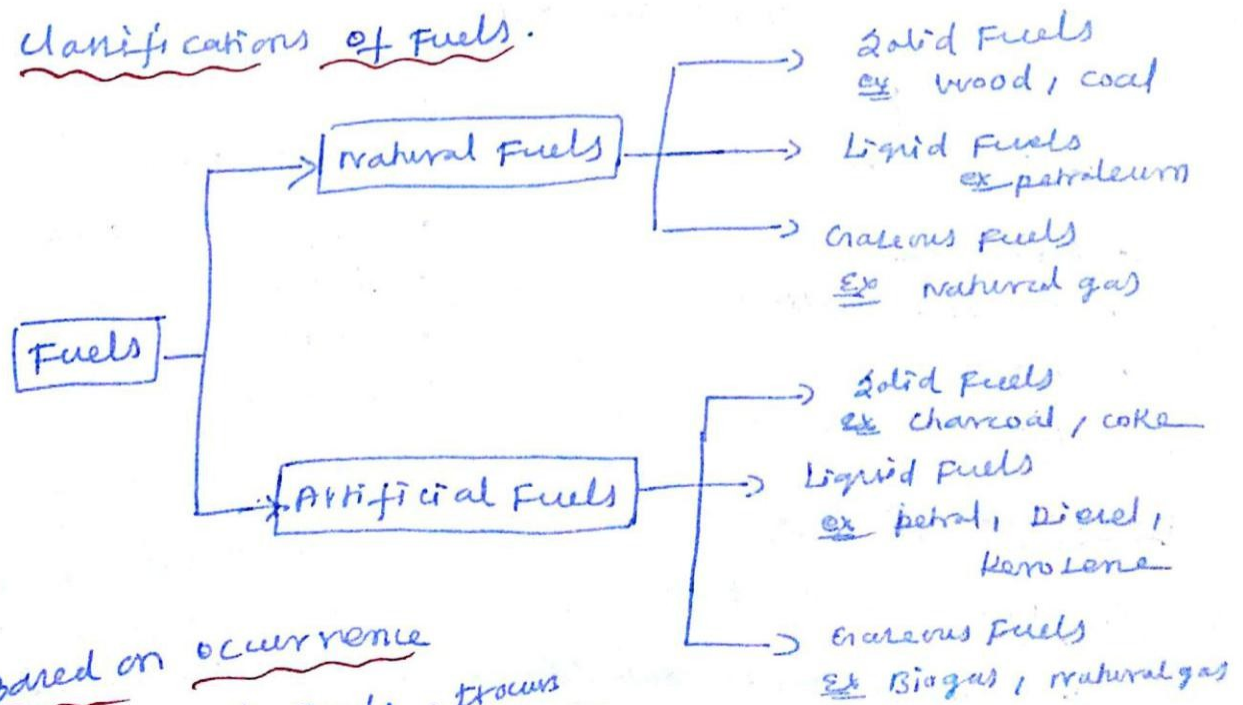
Example

wood, coal, coke, petrol, Lpg, crn

Fuel + O₂ → products + heat

characteristics (or) requirements of a good fuel.

1. It should be cheap and readily available.
2. It should not undergo spontaneous combustion.
3. It should have higher calorific value.
4. It should have moderate ignition temperature.
5. The products of combustion should not be harmful.

Classifications of Fuels.Based on occurrence

1. Natural Fuels : ^{trous} Directly from the nature are called as natural (or) 1st Fuels.
- Ex Coal, petroleum, natural gas

Artificial Fuels

It derived from 1st fuels are called artificial or secondary fuels.

Ex

coke, diesel, kerosene

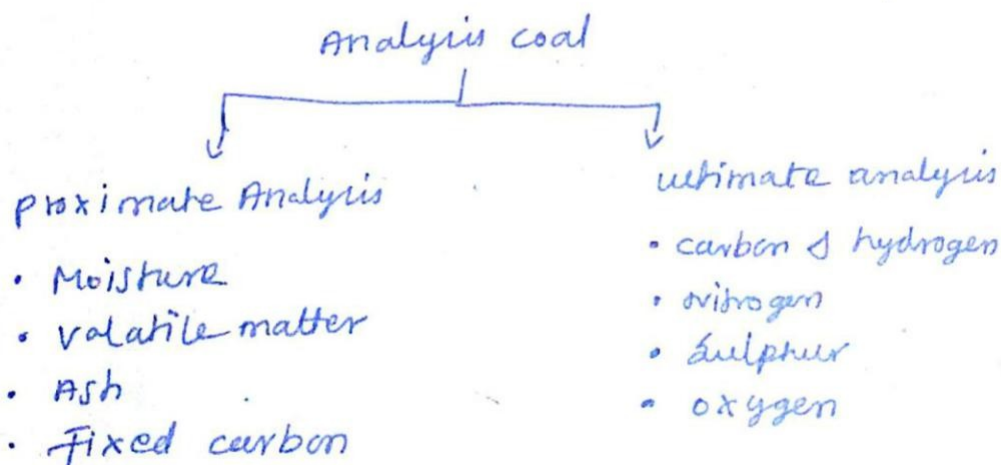
Based on physical state

1. Solid Fuels → coal, coke, lignite etc
2. Liquid " → Diesel, gasoline.
3. Gas. " → natural gas, coal gas etc.

Analysis of coal

The quality of coal is determined by two methods.

- i) proximate analysis
- ii) ultimate "

proximate Analysisi) Moisture content

• About 1g of coal sample is taken in a crucible and heated at 105-110°C in an electric hot air oven for one hour.

• Loss in weight & loss of moisture is calculated

$$\% \text{ of moisture} = \frac{\text{Loss in weight}}{\text{weight of coal sample taken}} \times 100$$

3

Significance High moisture content in coal is undesirable because it.

- ✧ It reduces the calorific value of coal
- ✧ It increases the transport cost
- ✧ It reduces the calorific value of coal

volatile matter

- ✧ Moisture free coal is taken in a crucible.
- ✧ Lid is placed on it to cut the air and heated in a muffle furnace maintained at $925^\circ \pm 20^\circ\text{C}$ for 7 minutes.
- ✧ crucible is cooled in a desiccator and weighed.
- ✧ calculated the loss of weight and % of volatile matter

$$\% \text{ of volatile matter} = \frac{\text{Loss in weight}}{\text{weight of coal sample taken}} \times 100$$

Significance High % of volatile matter is undesirable because

- ✧ It reduces the calorific value of coal.
- ✧ It has low ignition temperature.
- ✧ It burns with a long yellow smokes flame

Ash content

- ✧ After the analysis of volatile matter, the crucible with residual coal sample is heated in an open crucible $700 \pm 50^\circ\text{C}$ for half an hour in a muffle furnace.

- ✧ Loss of weight of the sample & % of the ash content calculated

$$\% \text{ ash content} = \frac{\text{weight of ash content}}{\text{weight of coal sample taken}} \times 100$$

Significance High % of ash content is undesirable because

- + It reduces the calorific value of coal.
- + It is harder and stronger.
- + It increases transporting, handling, storage.

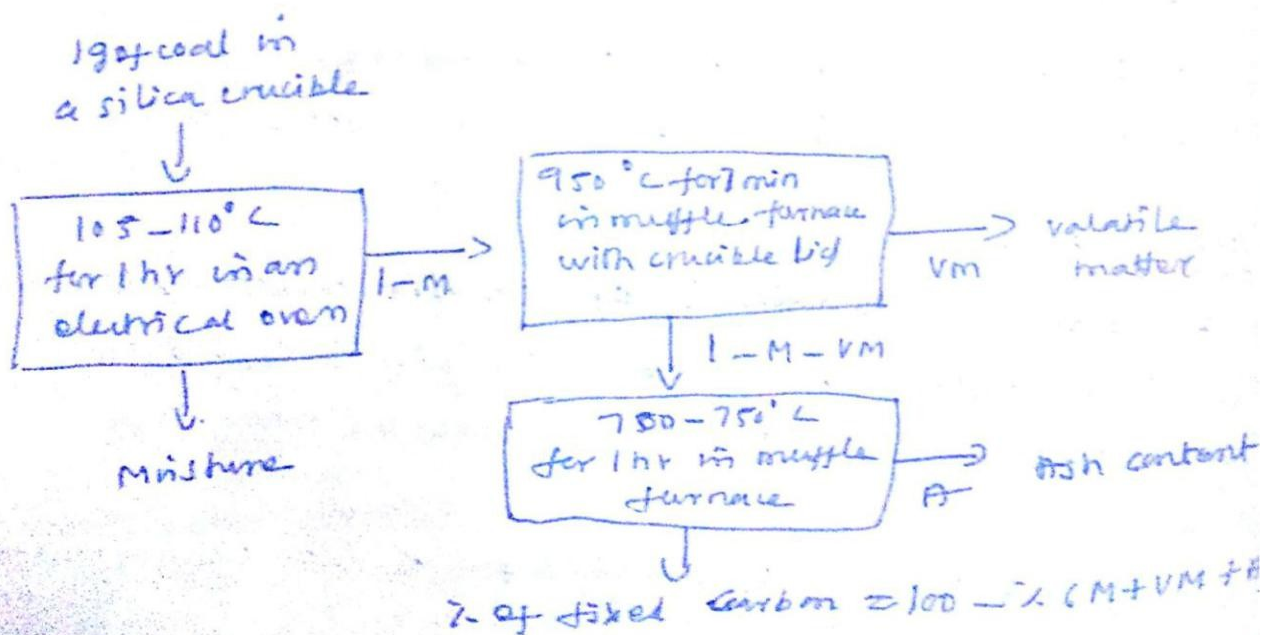
fixed carbon

It is reported as the difference between 100 and the sum of the % of moisture, volatile matter and of the fuel.

$$\% \text{ of fixed carbon} = 100 - \% \text{ of (moisture + volatile matter + ash)}$$

Significance : Higher % of fixed carbon is desirable because

- + Higher % of fixed carbon in a coal, higher will be its calorific value.
- + Helps in designing the furnace and shape of the fire box.



Ultimate Analysis

Definition

* The ultimate analysis involves the determination of % of carbon, hydrogen, nitrogen, sulphur and oxygen in coal.

* It is also called elemental analysis (or ~~Ultimate~~ ^{Ultimate} Analysis)

1. Carbon and hydrogen

* A known weight of coal is subjected to complete combustion in a stream of pure oxygen in a combustion tube.

* Carbon & hydrogen are converted into CO_2 & H_2O

* They are absorbed separately in anhydrous KOH & CaCl_2 bulbs respectively.

* The % of C & H are calculated.

$$\% \text{ of carbon} = \frac{\text{Increase in weight of KOH bulb} \times 12 \times 100}{\text{weight of coal sample taken} \times 44} \times 100$$

$$\% \text{ of hydrogen} = \frac{\text{Increase in weight of } \text{CaCl}_2 \text{ bulb} \times 2 \times 100}{\text{weight of coal sample taken} \times 18} \times 100$$

Significance

* Higher the % of C & H better is the quality of coal and higher is its calorific value.

* The percentage of carbon is helpful in assessing the rank of coal.

Nitrogen

- * Nitrogen in coal is determined by the Kjeldahl method.
 - * A known wt of powdered coal is oxidised by heating with concentrated H_2SO_4 along with K_2SO_4 & $HgSO_4$.
 - * Nitrogen coal is converted into ammonium sulphate a clear solution is obtained.
 - * The clear solution is treated with caustic alkali and liberated NH_3 is distilled over and absorbed in a known volume of std. acid solution.
 - * The unused acid is determined by titrating with std. $NaOH$.
 - * The volume of acid used, % of N_2 in coal calculated
- $$\% \text{ of } N_2 = \frac{\text{volume of acid used} \times \text{normality of acid used}}{\text{weight of coal sample taken}} \times 1.4$$

Significance

- * Good quality of coal should have very little content of N_2
- * When coal is carbonized the nitrogen & H_2 combine to form ammonia & is recovered as ammonium sulphate as a good fertilizer

Sulphur

- * Sulphur present can be determined by the Eschka method.
- * Sulphur is converted into soluble sulphate by incinerating coal with a 1:2 mixture of

Na_2CO_3 and calcined MgCO_3 is treated with BaCl_2
 to form barium sulphate precipitated

* The weight of BaSO_4 obtained sulphur calculated.

$$\% \text{ of Sulphur} = \frac{\text{Volume of } \text{BaSO}_4 \text{ ppt} \times 13.73}{\text{weight of coal sample taken}}$$

Significance

- * Sulphur increases the calorific value of coal.
- * The harmful gases like SO_2 & SO_3 will create air pollution

Oxygen

The % of O_2 in coal is calculated by difference

$$\% \text{ of } \text{O}_2 = 100 - \% \text{ of } (\text{C} + \text{H} + \text{N} + \text{S})$$

Significance

- * Lower the % of oxygen higher is its calorific value.
- * O_2 content increases its moisture holding capacity increases.

comparision between proximate and ultimate Analysis

- | | |
|--|--|
| - % of fixed or carbon, volatile matter, moisture and ash | Determines all elements Component of coal C, H, O, S, N |
| R. Use to find out heating value (GCV) | useful for furnace design |
| R. gives idea for the utility / type / rank of the coal | Helps to calculate the quantity of air required for complete combustion of coal. |

Metallurgical coke

Coke

↳ when bituminous coal is heated strongly in the absence of air, it loses volatile matter & converted into white, lustrous, dense, strong, porous and coherent mass is known as coke.

↳ This process of converting coal into coke is known as carbonization

Metallurgical coke

Coke is largely used in metallurgical industries as a reducing agent, so it is called metallurgical coke.

properties of metallurgical coke:

1. purity → Metallurgical coke should be low & the calorific value by moisture & ash.
2. porosity → O₂ contact easily and combustion more efficient
3. strength → strong & hard compact
4. size → Big size → uniform heating is never
Small size → choking will result.
5. calorific value → high
6. cost → cheap
7. combustibility → burn easily
8. Reactivity → low & high T on combustion

Comparison of coal & coke

<u>Coal</u>	<u>Coke</u>
1. Low strength & porosity	High strength & porosity
2. It is a natural fuel	Secondary fuel
3. High moisture & volatile	Low moisture & volatile
4. Burns in long time	Burns with short flame

Why coke is superior as a metallurgical fuel

- * Coke is stronger & more porous than coal.
- * By coking much of undesirable sulphur is removed.
- * Coke does not contain much volatile matter than coal.
- * Coke burns with a small flame & without smoke

Manufacture of Metallurgical coke by

otto - Hoffmann's coke method
(or)

By-product oven method

- * coke can be manufactured by otto - Hoffmann's method.
- * otto - Hoffmann developed a modern by-product coke oven to increase the thermal efficiency of the carbonization process and to recover valuable by products.

Description of oven

- * The oven consists of a number of siliceous chambers.
- * Each chamber is about 10-12m long 3-4m height and 0.4-0.45m wide.
- * Each chamber is provided with a charging hole at the top.
- * It is also provided with a gas off take valve and iron door at each end for discharging.

Working

- * Coal is introduced into the siliceous chambers the chambers are closed.
- * The chambers are heated to 1200°C by burning the preheated air and the product gas mixture in the inter spaces between the chambers.
- * The air & gas sending in 2nd & 3rd regenerators to $T = 1000^{\circ}\text{C}$
- * 1st & 4th regenerators heated by hot flue gases
- * 2nd & 3rd regenerators are used for heating incoming air & gas mixture.
- * The above system of recycling the flue gas to produce heat energy is known as regenerative system of heat economy.
- * Complete carbonization takes in 12-20h & yield 70%

Recovery of by-products

1. Tar

Tar is not get dissolved is collected in a tank below, which is heated by steam coils to recover back the ammonia sprayed.

2. Ammonia gas passed through another tower in which water is sprayed. It get converted to NH_4OH

3. Naphthalene

The gases are again passed through a tower cooled water is sprayed. Naphthalene gets condensed.

4. Benzene

The gases passed through the another tower where petroleum is sprayed.

Here benzene get condensed to liquid

5. Hydrogen sulphide

* The remaining gases passed through a purifier with moist Fe_2O_3 . Here H_2S is retained.

Final gas left out pure coal gas used as a gaseous fuel.

Advantages

* The carbonisation time is less.

* Valuable by products like NH_3 , Coal gas, naphthalene etc are recovered.

* Heating is done externally by producer gas

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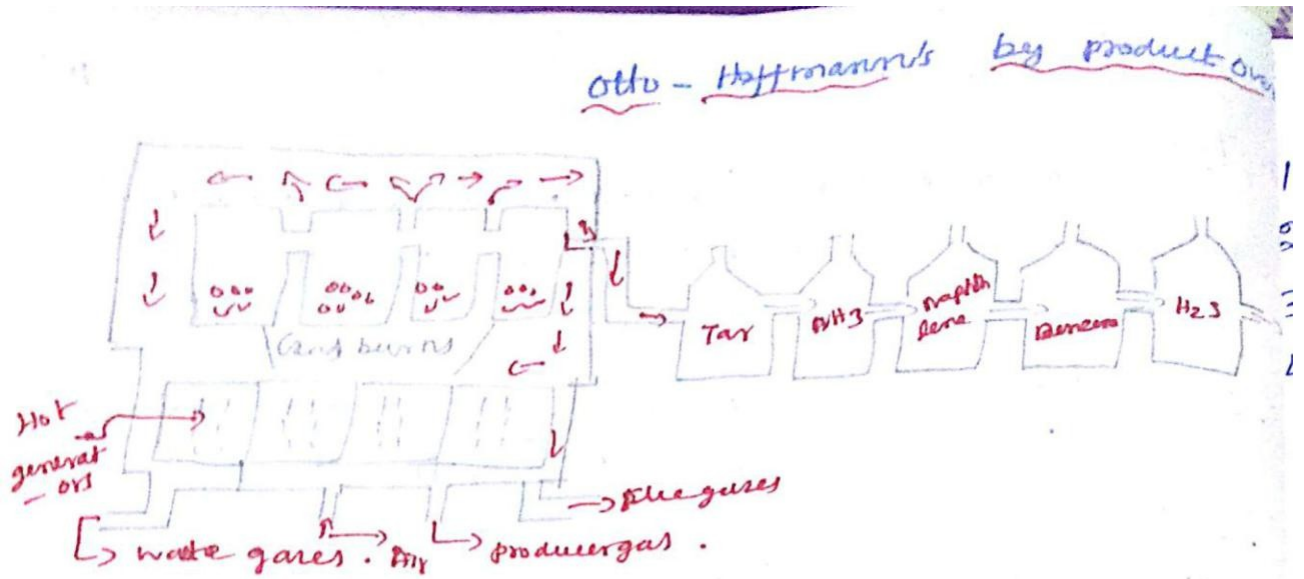
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Liquid fuels

Petroleum

- It is the naturally available liquid fuel.
- It is dark brown viscous liquid.
- Crude petroleum as such cannot be used.
- Hence it is subjected to refining.

Classification of petroleum

1. Paraffin base type crude oil
2. Asphaltic base type crude oil
3. Mixed base type crude oil

Refining of petroleum

The process of purification and separation of various fractions present in petroleum by fractional distillation is called refining of petroleum. It consists of two steps:

1. Removal of impurities
2. Fractional distillation

Impurities

1. water impurities from oil
2. NaCl & MgCl_2 "
3. Acidic & basic
4. Sulphur

It consists of two steps.

Fractional distillation.Removal method by ¹³

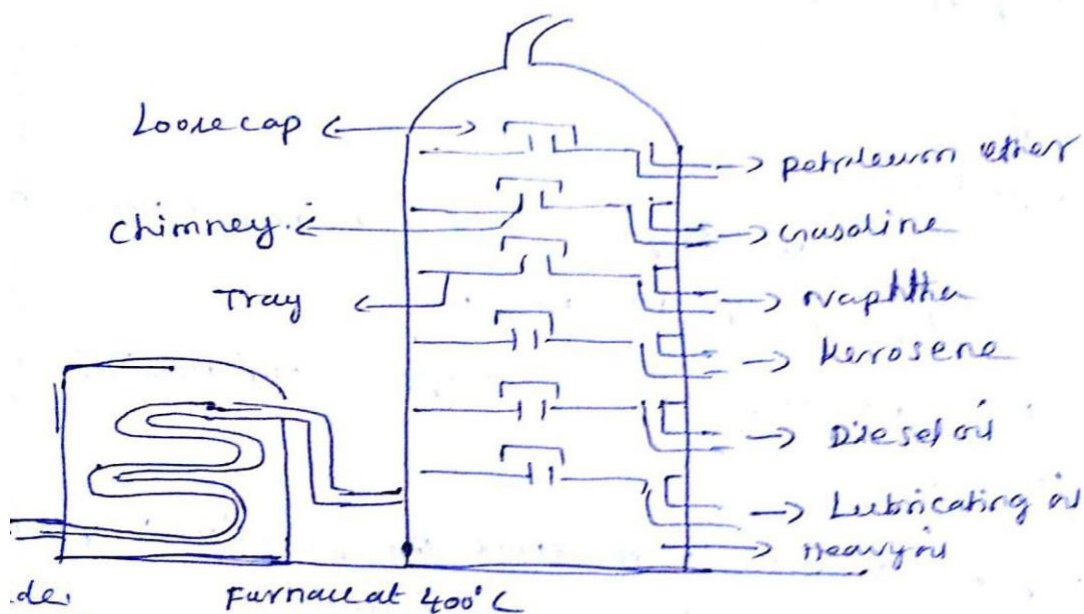
Collins's process

electrical desalting

conc. H_2SO_4 wash

Sodium plumbite

(or) cuprous oxide



name of the fraction	Hydrocarbon in terms of 'C' atoms	B.p	Applications
uncondensed gas	C_1 to C_4	< 30	Lp in domestic fuel.
petroleum ether	C_5 to C_7	30-70	solvent for varnish, paint
gasoline or petrol	C_5 to C_8	40-120	Fuel for automobiles & aeroplanes
Naphtha or solvent	C_9 to C_{10}	120-180	Solvent in dry cleaning
Kerosene oil	C_{10} to C_{16}	180-250	Domestic fuel, jet engine fuel
diesel oil or gas	C_{15} - C_{18}	250-320	Diesel engine fuel
Heavy oil	C_{17} to C_{30}	320-400	To produce 'cracked petrol'

- * Above 400°C obtained petroleum coke & Asphalt
- * Asphalt is used for water proofing roof and road making ^{city}
- * petroleum coke is used for moulding arc light rods.
- * Heavy oil further fractional distillation^{to} give

1. paraffin wax
2. vaseline
3. Lubricating oil
4. Grease.

- * The crude oil is then fractional distillation to give
 1. petrol
 2. Middle oil
 3. heavy oil

Knocking

Definition

It is a kind of explosion due to rapid pressure rise occurring in an IC engine.

Causes of knocking in S.I (spark ignition) Eng (petrol engines)

- * In a petrol engine a mixture of gasoline vapour air at 1:17 ratio is used as fuel.
- * The mixture is compressed by piston down the cyl
- * If the combustion proceeds in a regular way there is no problem in knocking.
- * The rate of ignition increases and explosive sound known as knocking.
- * Knocking property of the fuel reduces the efficiency of engine

Chemical structure and Knocking

The knocking tendency decreases the following order
 straight chain paraffins > Branched chain paraffins >
 cycloparaffins > olefins > Aromatics.

Improvement of anti knock characteristics prevention

- * octane number of the latter can be improved
- * Addition of anti-knock agents like Tetra-Ethyl Lead (TEL)
- * Now-a-days aromatic phosphates are used as anti knock agent because it avoids lead pollution.

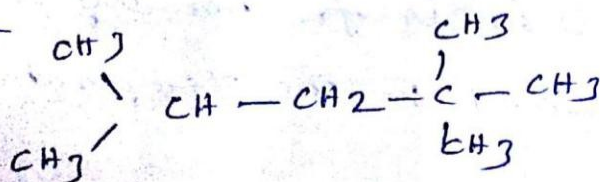
Octane number (or) Octane Rating

Definition

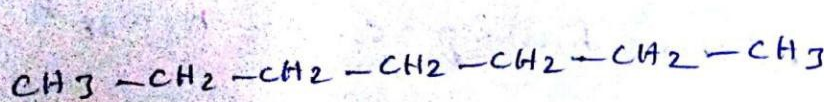
* Thus, octane number is defined as the % of iso-octane present in a mixture of iso-octane and n-heptane.

* It is introduced to express the knocking characteristics of petrol.

Example



Iso-octane
 octane number = 100



n-Heptane
 octane
 number = 0

Leaded petrol Anti-knock agent

Definition

The petrol containing tetra ethyl lead is called Leaded petrol.

Mechanism of Knocking

- * TEL decomposes thermally to form ethyl free radicals.
- * Growing free radicals of knocking process stopped the growth chain.

Disadvantages of using TEL

- * TEL is converted to lead oxide & metallic lead.
- * Ethylene dibromide is added with TEL to give Pb & PbO to give volatile lead bromide.



- * It creates atmospheric pollution.

Diesel oil

Definition

- * When crude oil is fractionally distilled, diesel oil is obtained in the temperature range 250 - 320°C.

* It is a mixture having $\text{C}_{15}\text{H}_{32}$ to $\text{C}_{18}\text{H}_{38}$ hydrocarbons.

• Its calorific value is 11000 Kcal/kg.

lives

Very good fuel in CI engines (or) diesel engines.

Ignition delay con ignition lag

* The combustion of a fuel in a diesel engine is not ~~sp~~ instantaneous and the time between injection of the fuel and its ignition is called ignition delay or ignition lag.

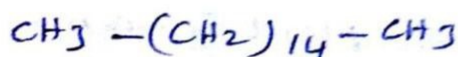
- ✓ Long ignition delays under go explosion.
- ✓ Shot " " " diesel knock will not occur.

Cetane number (or) Cetane Rating

Definition

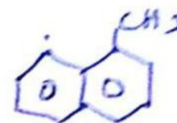
It is defined as the percentage of hexa decane present in a mixture of hexa decane & 1-methyl naphthalene, which has the same ignition lag as the fuel under test

example



n-hexane (hexadecane)

o Line number = 100



2-methyl naphthalene
(octane number = 0)

cetane number decreasing order

straight chain paraffins > cycloparaffins > alkyds

> Branched paraffins > Aromatics

Gaseous Fuels1. Natural GasDefinition

* It is always found above the gasoline or Diesel oil in the oil wells.

* It is also called Marsh gas.

* It consists of methane and other saturated hydrocarbons.

* calorific value 12000 - 14000 Kcal/m³.

Composition

<u>Constituents</u>	<u>%</u>
Methane (CH ₄)	88.5
Ethane (C ₂ H ₆)	5.5
Propane (C ₃ H ₈)	4
Butane (C ₄ H ₁₀)	1.5
Pentane (C ₅ H ₁₂)	0.5

* If natural gas contains lower hydrocarbons like CH₄, C₂H₆ is called as Lean or dry gas

* If natural gas contains higher hydrocarbon like C₃H₈, C₄H₁₀ is called rich or wet gas

Production

Decomposition of plant & animal matter exposed to intense heat & pressure under the surface of earth over millions of years.

Uses

- * Domestic fuel & Industrial fuel
- * Chemical manufacture of plastics & organic chemicals
- * Fuel for vehicles.

Liquefied petroleum gas (Lpg)

- * It is also known as bottled gas or refinery gas
- * It is obtained as a by-product during fractional distillation of crude petroleum oil or cracking heavy oils or from natural gas.
- * It mainly contains propane & butane.
- * It can be readily liquefied under pressure.

composition

<u>constituents</u>	<u>%</u>
n-Butane	38.5
iso butane	37.0
propane	24.5

uses

- * Domestic & Industrial fuel
- * motor fuel.

Advantages of Lpg over other gaseous fuels

1. It has high calorific values
2. It can be easily ignited
3. It can be controlled easily
4. Does not produce ash & smoke
5. Transported easily in pipelines
6. It can be stored in a small place
7. It is less of health hazard, even in case of leakage
8. need little care for maintenance.
9. It can be directly used in internal combustion engine

Disadvantages of LPG over other gaseous fuels.

1. Leakage cannot be easily detected, due to its faint odour.
2. Its octane value is low
3. Handling must be under high pressure.

power alcohol.

Definition

* When ethyl alcohol is blended with petrol at concentration of 5-10%.

* It is called power alcohol.

* Absolute alcohol (100% ethyl alcohol) is also called as power alcohol.

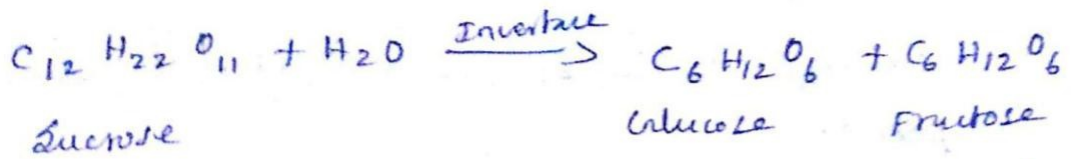
production of ethyl alcohol.

* Ethyl alcohol can be synthesised from hydrocarbon carbohydrates, starch and molasses.

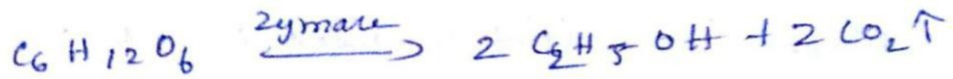
* Molasses contains about 60% sucrose, glucose & fructose.

1. Molasses is diluted with water to bring the sugar concentration to about 10%.
2. The nutrients like ammonium phosphate and ammonium sulphate are added.
3. Dilute H_2SO_4 is added to bring the pH value between 4 & 5.
4. The 'T' of the mixture is maintained at about 30°C.
5. Catalyst the fermentation yeast is added.

6. Invertase enzyme converted into glucose & fructose



7. Zymase enzyme converted into glucose & fructose into ethyl alcohol & CO_2



glucose 6p
fructose:

8. The fermented liquid called wash contains about 20% alcohol.

9 - Fractional distillation to get rectified spirit which contains about 95% alcohol.

10. Absolute alcohol (100% alcohol), the rectified spirit is digested with lime (CaO) for 2 days & then distilled.

Advantages

1. Octane value alcohol has 90, petrol is only 70.
Hence, addition of alcohol to petrol increases the octane value.

2 - Alcohol - petrol blends have lesser starting difficulties.

2. Alcohol is capable of absorbing any traces of moisture.

4- It is cheaper than petrol.

Disadvantages

1. calorific value of power alcohol is lower than petrol.
2. output power is reduced upto 35%
3. It is difficult to atomise alcohol at low T
4. Alcohol is easily oxidised to acids. Hence alcohol may cause corrosion.
5. It contains O_2 atom, the amount of air required for combustion is less, the engine and carburetor need to be modified

compressed natural gas. (CNG)Definition

- * When the natural gas is compressed, it is called compressed natural gas.
- * It derives from natural gas
- * CNG present is methane.
- * When the petroleum natural gas occurs along with petroleum in oil wells it is called wet gas
- * When the petroleum natural gas occurs along with crude oil it is called dry gas

composition

<u>constituents</u>		<u>%</u>
methane	CH_4	88.5
ethane		5.5
propane		3.7
Butane		1.8
		Pentane -

properties

1. crn is the cheap fuel.
2. It is less expensive than petrol & diesel
3. crn requires more air for ignition.

uses

To run an automobile vehicle just like Lpn.

Bio - dieselDefinition

It refers to a vegetable oil or animal fat based diesel fuel consisting of long chain alkyl (methyl, ethyl, propyl) esters.

Sources

Sunflower, rape seed, Soyabean, jayoba, neem, palm oil, coconut, hemp, algae, chuket fat, Sewage sludge^{en}

production of Bio-diesel from rape seed.

1. production of rape seed oil by crushing of rape seed.
2. Rape seed oil + methanol $\xrightarrow[50^\circ\text{C}]{\text{NaOH}}$ glycerol + diester
2. glycerol is allowed to settle
4. Diester is purified and is used as bio-diesel.

Advantages

1. It is non-toxic
2. It is used as vehicle Fuel in 2005 & railway in 2007 aircraft in 20011
3. It emits less smoke
4. Its yield energy is high.
5. The raw materials are renewable
6. It has best engine performance

problem in using vegetable oil as fuels.

1. The viscosity of vegetable oils are high, so atomisation is poor.
2. oxidation & thermal polymerisation of vegetable cause deposit formation.
3. High viscosity causes misfire & ignition delay.
4. The use of vegetable oils as fuel requires the modification of the conventional diesel engine.

combustionDefinition

It is a process of rapid exothermic oxidation in which a fuel burns in the presence of O_2 with the evolution of heat & light.

calorific value : Definition

The total amount of heat liberated, when unit mass of fuel is burnt completely.

units of calorific value

1. calorie 2. kilocalorie 3. BTU 4. C.H.U

calorie : Definition

The amount of heat required to raise the temperature of 1 gram of water through $1^\circ C$ ($15^\circ C$ to $16^\circ C$) is known as calorie.

Higher (or) Gross Calorific value (GCV)

25

Definition
The total amount of heat produced when a unit quantity of the fuel is completely burnt and the products of combustion are cooled to room T

Lower (or) Net Calorific value (NCV)

It is defined as the net heat produced, when a unit quantity of the fuel is completely burnt and the products of combustion are allowed to escape

$$\begin{aligned} \text{NCV} &= \text{GCV} - \text{Latent heat of condensation of water vapour produced.} \\ &= \text{GCV} - \text{mass of hydrogen} \times 9 \times \text{Latent heat of condensation of water vapour} \end{aligned}$$

Theoretical calculation of calorific values

GCV (or) HCV

$$= \frac{1}{100} \left[8080C + 34500 \left(H - \frac{O}{8} \right) + 2240S \right] \text{ Kcal/kg}$$

$$\text{NCV (or) LCV} = \left[\text{HCV} - \frac{9}{100} H \times 587 \right] \text{ Kcal/kg.}$$

Ignition temperature (IT)

Definition

The lowest temperature to which the fuel must be heated, so that it starts burning smoothly.

Spontaneous Ignition Temperature (SIT)

Definition

The minimum 'T' at which the fuel catches fire (ignites) spontaneously without external heating.

Explosive range

Definition

The range covered by the lower and upper limits of the fuel is known as explosive range of the fuel.

Example

Explosive range

Hydrogen	6 - 71
Methane	6 - 13
Petrol vapour	2 - 4.5

When the composition of the gas-air mixture is within its explosive range, then fire accidents may be caused.

Flue gas Analysis (ORSAT method)

Flue gas

Definition

The mixture of gases like CO_2 , O_2 , CO coming out from the combustion chamber is called flue gas.

description of orsat's apparatus

21

- * It consists of a Horizontal tube.
- * At one end of this tube U-tube containing fused CaCl_2 is connected through 3-way stop cock.
- * The other end of this tube is connected with a graduated burette.
- * The burette is surrounded by a water-jacket to keep the 'T' of gas constant.
- * The Level of water in the burette can be raised or lowered by raising or lowering the reservoir.
- * Three different absorption bulbs 1, 2 & 3 for absorbing CO_2 , O_2 & CO

<u>Bulb</u>	<u>Reagent</u>	<u>Function</u>
1	KOH	Absorbs only CO_2
2	Alkaline pyrogallol solution	Absorbs CO_2 & O_2
3	Ammonical cuprous chloride solution	Absorbs CO_2 , O_2 & CO

working

- * The 3-way stop-cock is opened to the atmosphere and the reservoir is raised, till the burette is filled with water & air.
- * The 3-way stop-cock is now connected to the flue gas.
- * The volume of flue gas is adjusted to 100cc by raising and lowering the reservoir.
- * 3-way stop cock is closed.

Absorption of CO_2

- * All the gas is passed into the bulb - 1 by raising the level of water in the burette.
- * CO_2 absorbed by KOH

Absorption of O_2

- * Bulb - 1 closed and stop cock of bulb - 2 is opened.
- * O_2 absorbed by alkaline pyrogallol.

Absorption of CO

- * Bulb - 2 is closed and stop-cock of bulb - 3 is opened.
- * remaining gas sent into the bulb - 3.
- * CO present absorbed by ammoniacal cuprous chloride.
- * The remaining gas in the burette after the absorption of CO_2 , O_2 & CO is taken as nitrogen.

Significance & uses of flue gas analysis

1. Flue gas analysis gives the complete & incomplete combustion process.
2. If the analysis of a flue indicates the presence of CO , it indicates the incomplete combustion.
3. If there is considerable amount of O_2 , it shows the complete combustion.

Precautions

1. Care must be taken in such a way that, there is no leakage in the absorption bulb 1, 2 & 3 should be brought to the etched marked level one by one by raising

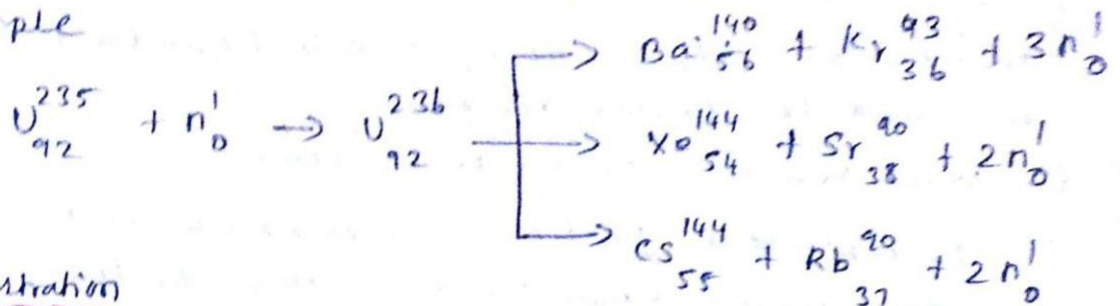
Unit V Energy Sources and Storage devices

Energy Sources

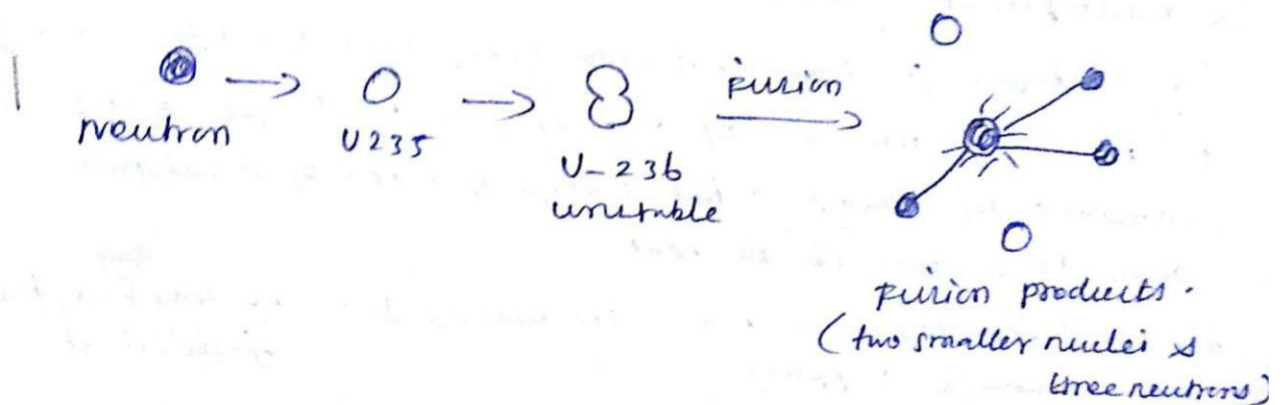
Nuclear fission: Definition

The process of splitting of heavier nucleus into two or more smaller nuclei with simultaneous liberation of large amount of energy.

Example



Illustration



Nuclear fission a large amount of energy is released.

characteristics of nuclear fission

1. A heavy nucleus U^{235} or Pu^{239} when bombarded by slow moving neutrons, split into two or more nuclei.
2. Two or more neutrons are produced by fission of each nucleus.
3. Large quantities of energy is produced as a result of conversion of small mass of nucleus into energy.

- All the fission fragments are radioactive, giving off β and γ -radiations.
- 5. The atomic weights of fission products ranges from about 70 - 160
- 6. All the fission reactions are a self-propagating chain reactions.
- 7. The nuclear chain reactions can be controlled and maintained by adsorbing a desired number of neutrons and used in nuclear reactor.
- 8. chain reaction cannot be maintained
- 9. Multiplication factor :- the number of neutrons, resulting from a single fission / is known as the multiplication factor.

Advantages of nuclear fission energy over fossil fuels energy

1. A small amount of nuclear fuel U^{235} gives a large amount of energy. but a large quantity of fossil fuel gives large amount of heat.
2. long period of time taken the energy from nuclear fuel continuously supplied " " " " fossil fuel.

Disadvantages of nuclear fission energy over fossil fuels energy

1. nuclear fission causes more serious pollution than the burning of fossil fuels.
2. Biggest problem of using nuclear fission energy waste but no problem in fossil fuel.

Nuclear fusion : Definition

The process of combination of lighter nuclei into heavier nuclei with simultaneous liberation of large amount of energy.

Illustration

3

process

Deuterium + Tritium $\rightarrow$ Helium $\rightarrow$ Energy
(free neutron)

1. the energy of stars and sun is arising from the fusion reactions in which hydrogen is converted into He.
2. The combination of these nuclei is very difficult because all the nuclei are +ve charged.
3. It electrostatic repulsion takes place
4. H_2 to He fusion reaction at 100 million degree centigrade.
5. Start fusion reaction, T at high order must be reached. That is why it is called thermonuclear reactions.

Example

In Hydrogen bomb, fusion occurs by the fission of atom bomb, which acts as trigger.

Disadvantages

Design of thermonuclear fusion power plant is very difficult.

characteristics of nuclear fusion

1. unlike nuclear fission, there is no limit on the amount of fusion.
2. Distance between the nuclei is of the order of one fermi.

3. The amount of energy in fusion is four times more compared to that of fission.
4. Sufficient amount of kinetic energy must be provided to facilitate a fusion reaction.
5. As electrostatic repulsion increases with increase in atomic number of nuclei.

nuclear chain reactions

Definition

A fission reaction, where the neutrons from the previous step continue to propagate and repeat the reaction is called nuclear chain reaction.

critical mass

The minimum amount of fissionable material U^{235} required to continue the nuclear chain reaction is called critical mass.

a) Super critical mass

If the mass of the fissionable material U^{235} is more than the critical mass, it is called super critical.

b) Sub-critical mass

If the mass of the fissionable material is smaller than the critical mass, it is called sub-critical.

Nuclear Energy : Definition

The energy released by the nuclear fission or nuclear fusion is called nuclear energy.

cause of the release of energy

The loss in mass gets converted into energy.

according to Einstein equation

$$E = \Delta mc^2$$

$$\therefore \Delta m = (M - M')$$

c = velocity Δm = loss in mass E = energy

M = Mass of radioactive substance before emitting radiation

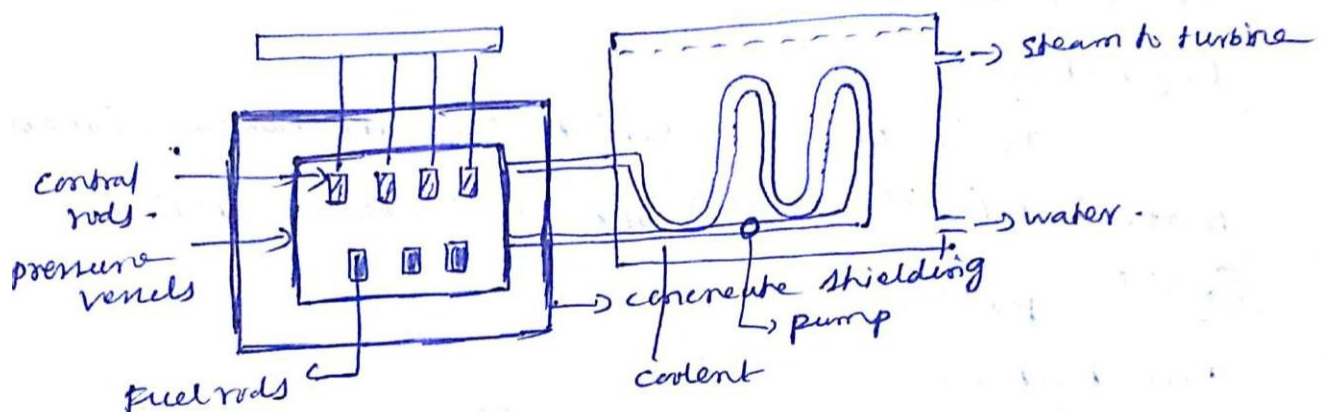
M' = " " " " " after " "

Light water nuclear - power plant

Definition

Light water nuclear power plant is a nuclear reactor in which U^{235} fuel rods are submerged in water.

water acts as moderator & coolant



working

* Fission reaction is controlled by inserting or removing the control rods of B^{10} .

* The heat emitted by fission of U^{235} in the fuel core is absorbed by the coolant.

* Transfers heat to sea water, which is converted into steam.

* The steam then drives the turbines, generating electricity.

pollution.

It is very important for production of electricity, they will cause a serious danger to environments.

problem on disposal of reactor waste

& Disposal of reactor waste is another important problem because the fission products Ba^{139} & Kr^{92} radioactive

& waste reactor packed in concrete barrels and buried deep in the sea.

& Salt water will not allow the radiation to come out

Breeder reactor

Definition

It is the one which converts non-fissionable material (U^{238} , Th^{232}) into fissionable material. (U^{235} , Pu^{239})

Illustration



Non-fissionable



Significance

1. The non-fissionable nucleides such as U^{238} , called fertile nucleides, are converted into fissionable nucleides.
2. The fissionable nucleides such as U^{235} & Pu^{239} are called fissile nucleides & efficiency is more

Solar energy conversionTwo mechanism

1. Thermal conversion
2. photo "

Thermal conversion

It involves absorption of thermal energy in the form of IR radiation.

Methods of thermal conversion

1. Solar heat collectors
2. Solar water heater.

photo conversion

Light energy $\rightarrow$ electrical energy

When the energy of solar radiation falls on the surface of a metal, it is absorbed and used to excite and eject e^- s & generate electric current

Methods of photo conversion

1. photogalvanic cell or solar cell

photo galvanic cell or solar cellDefinition

A device which converts the solar energy directly into electrical energy is called solar cell. It is otherwise called as 'photo voltaic cell'.

principle

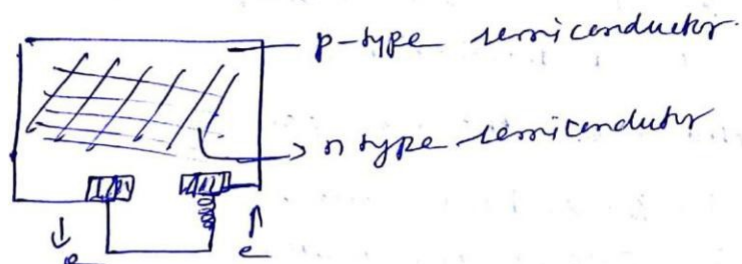
When sun rays fall on the two layers of semiconductor devices, potential difference between the two layers is produced.

- This potential difference causes flow of electrons & thus produces electricity.

Example : Silicon Solarcell

Construction

- It consists of a p-type & n-type.
- They are in close contact with each other.



Working

- When the solar rays fall on the top layer of p-type semiconductor, the electrons from the valence band in this layer get promoted to the conduction band.
- The conduction band e-s can easily cross the p-n junction into n-type semiconductor.
- Potential difference between two layers is created which causes flow of e-s.
- When this p- & n-layers are connected to an external circuit, electrons flow from n-layer to p-layer and hence current is generated.

Applications

1. It is used in street lights.
2. Water pumps are operated by using solar batteries.
3. ^{they are} used in calculators, watches, radios & TVs.
4. ^{they are} used in eco-friendly driving vehicles.

Space craft and Satellites

6. They are used in remote places and in forests to get electrical energy without affecting the atmosphere.

Advantages too Merits

1. Solar cells can be used in remote & isolated areas.
2. forests & hilly regions.
2. maintenance cost is low.
3. solar cells are noise & pollution free.
4. Their lifetime is long.
5. They operate at ambient temperature.
6. They need not be recharged.

Disadvantages (or) Demerits

1. capital cost is higher.
2. storage of solar energy is not possible.
3. It produces only DC voltage.
4. solar energy is not available throughout day and nights.

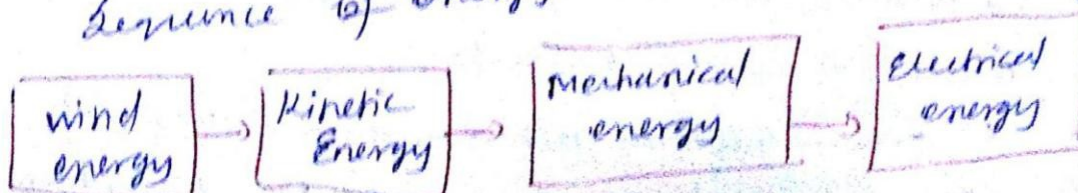
wind energy

- moving air is called wind.
 • Energy recovered from the force of wind is called wind energy.

Methods of harnessing wind energy

1. wind mill

Sequence of energy conversion.



construction & working of a wind mill

- * It consists of a wheel containing number of blades.
- * wheel rotates about an axle mounted on a pole.
- * The wind energy is used to rotate the wheel.
- * when the wind falls on the wheel of a wind mill it rotates and electric current is produced.

Kinetic energy $\rightarrow$ electrical energy.

wind farm

- * large number of wind mills are erected to produce electricity is called wind energy farm.

other methods

- a) Sky sail
- b) Ladder mill
- c) Kite ship (Large free-flying sails)
- d) Sky wind power (flying electric generator)
- e) Breeze technologies (Hoversing wind turbine)
- f) Segmotor automation. (The Kite wind generator)

Advantages -

- 1) Does not cause any pollution
- 2) very cheap & economic
- 3) It is renewable

Disadvantages

1. It produces the noise pollution by wind farms
2. Birds will cause hazards.
3. It ^{affected} produce electromagnetic signals & Radio signals.
4. It is not sufficient to operate very heavy machines.

uses of wind energy

- 1. move the sail boats in lakes, rivers & seas.
- 2. used to operate water pumps.
- 3. used to run the flour mills to grind the grains
- 4. used to produce electricity.

Storage devicesBattery : Definition

A battery is an arrangement of several electrochemical cells connected in series, that can be used as a source of direct electric current at constant voltage.

A cell : It contains only one anode & cathode

A Battery : It contains several anodes & cathodes.

Types of Battery

1. primary battery (or) 1st cells (or) non-reversible battery
2. Secondary Battery (or) 2nd cells (or) reversible battery.

primary battery : Definition

- 1. A primary battery is also called as 1st cell.
- 2. It can be discharged once & then discarded.

Example Dry cell, Leclanche cell.

Secondary battery : Definition

- 1. It is reversible reactions
- 2. It can be discharged and used again & again
- 3. They are also called storage cells or accumulators

Example : Lead acid storage cell, Ni-cd cell

Fuel battery or flow battery

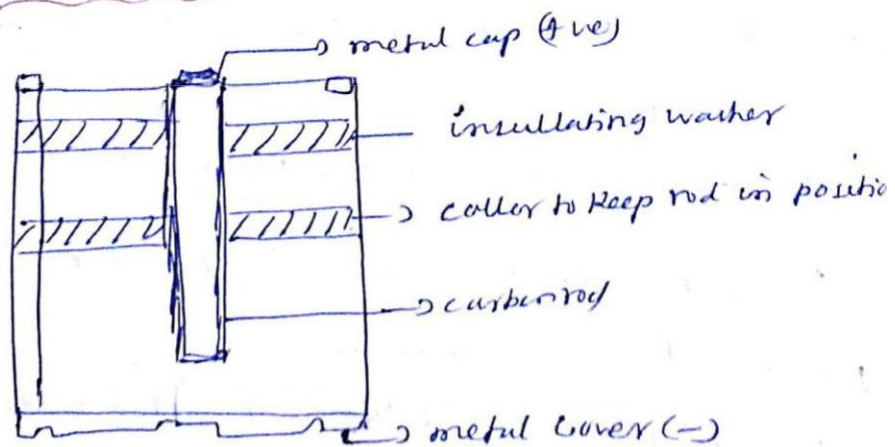
- It is an electrochemical cell.
- It converts chemical energy from a fuel into electric energy.

Example $H_2 - O_2$ cell
Aluminium - air cell

Important primary BatteryDry cell or Leclanche's cellDefinition

A cell without fluid component is called as dry cell.

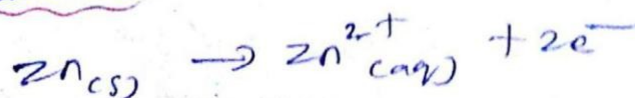
example Daniel cell, alkaline battery

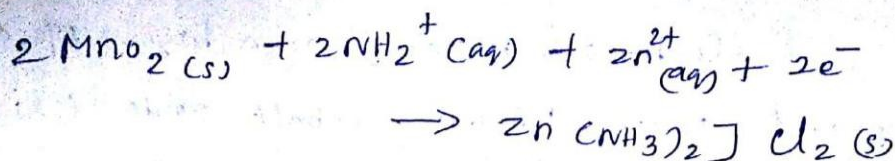
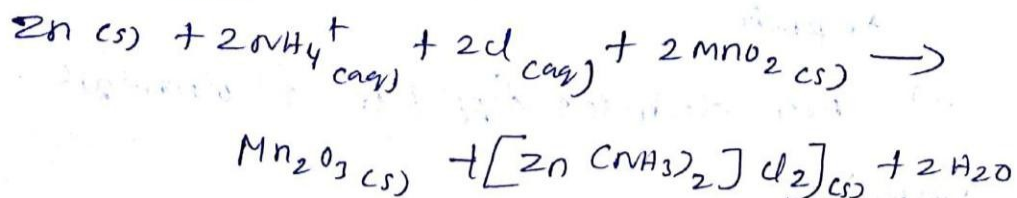
construction & working

Anode : Zinc container

cathode : graphite rod

Electrolyte : NH_4Cl , $ZnCl_2$ & MnO_2

Anode reactions

cathode reactionoverall reaction

- * It is primary cell. & reaction not reversible.
- * It is very cheap to make.
- * It gives voltage of about 1.5 V.

Disadvantages (or) demerits (or) Limitations

1. When current is drawn rapidly, drop in voltage occurs.
2. Since the electrolyte is acidic Zn dissolves slowly even if it is not in use.

uses

- * Flash light
- * transistor radios.
- * calculators. etc

Lithium - ion. batteries LIB (or) Lithium - ion cells

- * It is a secondary battery.
- * It is lithium cell.
- * Anode - porous carbon (negative electrode)
- * Cathode - Lithium-metal oxide (positive electrode)

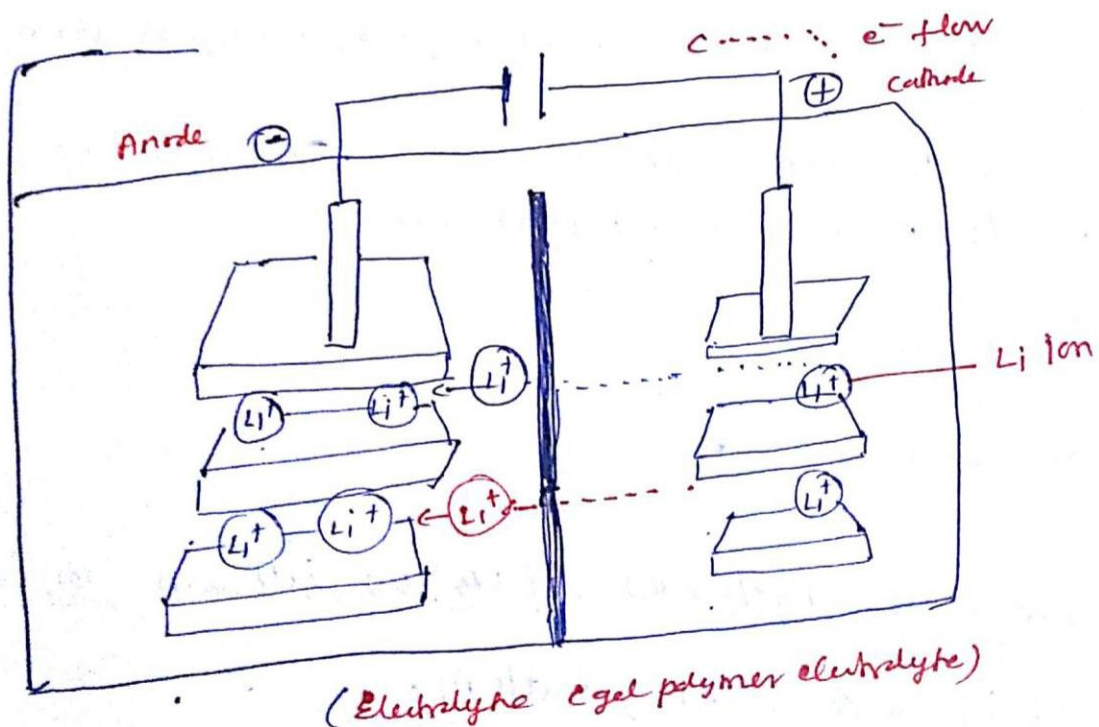
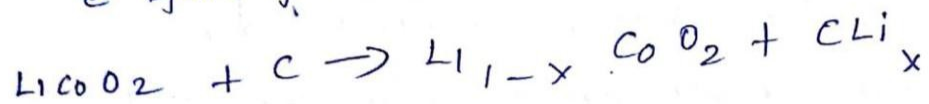
construction

- i) + electrode is made from a layers of chemical compound called Lithium - cobalt oxide (LiCoO_2)
- ii) - electrode is made from layers of porous carbon graphite.
- iv) Both electrodes dipped in gel electrolyte.

working

charging .

e^- flow from +ve to -ve electrode



Discharging : Deposit Li at +ve electrode.
 e^- flow from -ve to +ve electrode



Dis advantages

- × Recycling of this battery causes environmental hazards.
- × Mechanical strain & normal bumping reduces battery capacity.

H₂-O₂ Fuel cell (Green fuel cell)

Fuel hydrogen & the oxidiser - oxygen and the liquid electrolyte are continuously passed through the cell.

Description

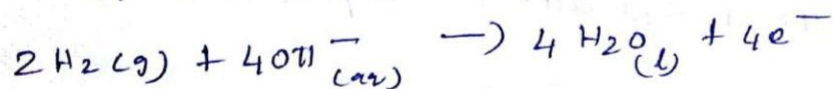
- × Two porous electrodes acts as cathode & anode
- × Electrolyte solution - KOH
- × catalyst - Pt, Pd, Ag
- × Two electrodes are connected through the voltmeter.

Working

Anode - H₂ - oxidised

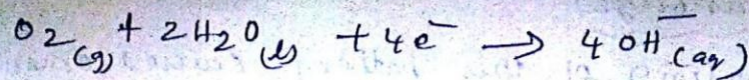
Cathode - O₂ - reduced.

Anodic reaction - H₂ reacts with ion in the electrolyte producing water & electrons

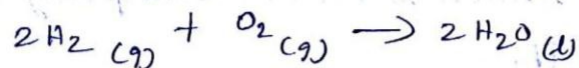


Cathodic reaction :

O₂ combines H₂O & electron to form the ion consumed by anode



overall reaction



Emf value of the cell is $\approx 0.8 - 1.0 V$.

uses

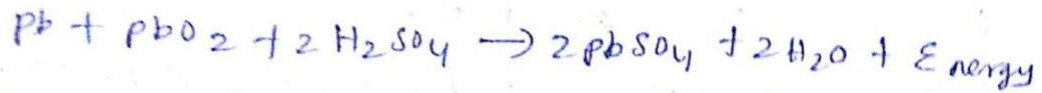
- * Submarines
- * military vehicles
- * fresh water by the astronauts.

Advantages

- * Efficiency is more than 75%
- * It is the lightest element, it can be transported easily from one place to another.
- * It can replace the use of batteries
- * It causes less noise pollution

Limitations & disadvantages

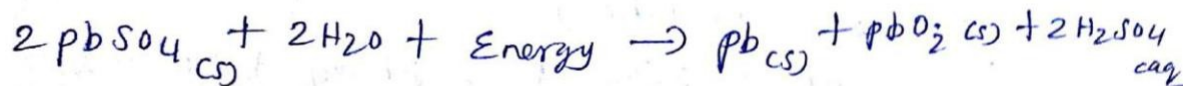
- * It is explosive
- * It is very expensive to be carried out
- * It is difficult to compress into liquid form.

Discharging (acts as voltaic cell)

- * PbSO_4 precipitated deposit on both electrodes & decrease in H_2SO_4 concentration.
- * So, the battery needs recharging.

Recharging.

- * By electric current in the opposite direction.
- * The electrode reaction gets reversed.
- * Pb is deposited on anode
- * PbO_2 , " " cathode
- * Increase the concentration of H_2SO_4

uses

- * cars, buses & trucks
- * gas engine ignition
- * telephone exchanges
- * power stations

Advantages

- * It is made easily.
- * It produces very high current
- * It also acts effectively at low temperature

Lead - acid storage cell

- * It is a secondary battery.
- * It can operate as a voltaic cell and as an electrolytic cell.
- * when it is recharged it operates as an electrochemical cell.

construction and working

Anode. - Pb plates

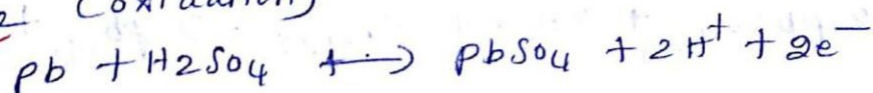
cathode - PbO₂ plates

Electrolyte - H₂SO₄ acid.

- * plates are arranged in parallel & separated by insulators like rubber or glass fibre

charging

Anode (Oxidation)



Cathode (Reduction)

