

K.RAMAKRISHNAN COLLEGE OF TECHNOLOGY, SAMAYAPURAM
DEPARTEMENT OF CHEMSITRY
UNIT I - WATER TECHNOLOGY
PART - A

1. Define hard water and soft water.

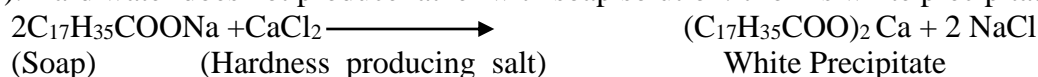
Hard water does not produce lather with soap solution readily, but forms a white precipitate. Hardness is due to presence of Ca and Mg salts.

Soft water readily gives lather with soap solution. It does not contain dissolved calcium and magnesium salts.

2. How is hardness of water detected?

Hardness can be detected by

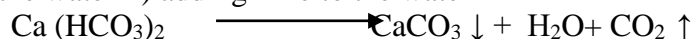
i). Hard water does not produce lather with soap solution. It forms white precipitate.,



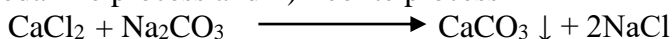
ii). it produces wine red colour with Eriochrome Black-T indicator at pH 9-10

3. Explain temporary and permanent hardness of water.

Temporary hardness: It is due to presence of bicarbonates of Ca and Mg. It can be removed by i) boiling the water ii) adding lime to the water



Permanent hardness: It is due to presence of chlorides and sulphates of Ca and Mg. It can be removed by i) sodalime process and ii) Zeolite process



4. Why CaCO₃ is used as standard for expressing hardness? Give the units of hardness.

CaCO₃ is used as standard for expressing hardness because,

(i) It is the most insoluble salt

(ii) Its molecular weight is 100, Equivalent weight is 50, and therefore calculation is simple

$$\text{Amount equivalent of CaCO}_3 = \frac{\text{Amt. of Hardness producing salt} \times 100 (\text{Mol. Wt of CaCO}_3)}{\text{Mol. Wt of Hardness producing salt}}$$

Units of hardness: a) Parts per million (ppm) b) Milligram per litre (mg/Lit)

5. Sample water contains 16.8 mgs of MgCO₃ and 8.1 mgs of Ca(HCO₃)₂. Calculate the hardness in terms of CaCO₃ equivalent.

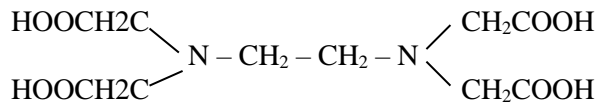
Solution:

$$\text{Amount equivalent of CaCO}_3 = \frac{\text{Amt. of Hardness producing salt} \times 100 (\text{Mol. Wt of CaCO}_3)}{\text{Mol. Wt of Hardness producing salt}}$$

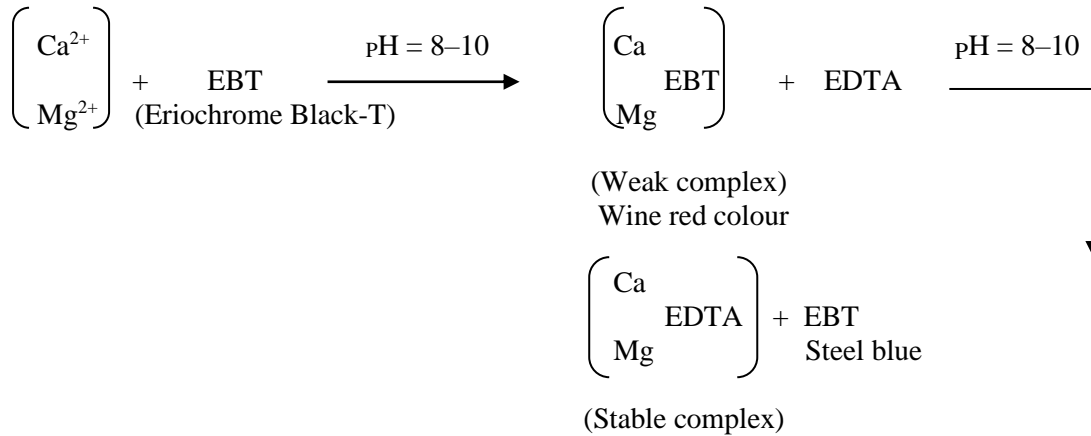
Name of the salt producing hardness	Amount in mg/Lit (Given Data)	Mol. Wt of given salt	Amt. Equivalent of CaCO ₃
MgCO ₃	16.8	84	$\frac{16.8 \times 100}{84}$ = 20 mg/Lit
Ca(HCO ₃) ₂	8.1	162	$\frac{8.1 \times 100}{162}$ = 20 mg/Lit

6. Draw the structure of EDTA and basic reaction (principle) of EDTA method.

Structure of Ethylene Diamine Tetra Acetic acid (EDTA):



Reaction (Principle) of EDTA method:



7. Mention the units used for expressing hardness of water.

Parts per million (ppm), or milligram per litre (mg/L).

8. What are the requirements of boiler feed water?

The water fed into the boiler for the production of steam is known as boiler feed water

It should be free from (i). Suspended solids. (ii). Dissolved salts like MgCl₂ (iii). Hardness. (iv). Alkalinity. (v). Dissolved gases like O₂ and CO₂

Hardness-<0.2ppm, Soda alkalinity-0.15-1ppm, Caustic alkalinity-0.15-0.45ppm, Excess soda ash-0.3-0.55ppm, Dissolved gases like O₂, CO₂-0 ppm

9. What are the disadvantages using hard water in boiler or what are boiler troubles?

1. Scale and sludge formation. 2. Caustic Embrittlement. 3. Priming and Foaming. 4. Boiler corrosion

10. Define scale and sludge formation in boilers.

Sludge is a soft, loose, slimy precipitate formed inside the boiler. (It is formed by substances like MgCl₂, MgCO₃ and CaCl₂)

Scale is a hard, adherent deposit formed on the inner surface of the boiler. (It is formed by substances like Mg(OH)₂, Ca(HCO₃)₂ and CaSO₄)

11. What is blow-down operation?

Blow-down operation is a process of removing a portion of concentrated water by fresh water frequently from the boiler during steam production

12. What are boiler compounds?

The chemicals directly added into the boiler for removing scale forming substances is known as boiler compounds. Ex: Sodium carbonate, Sodium phosphate, Sodium hexa meta phosphate and colloidal conditioning.

13. Distinguish between internal conditioning and external conditioning methods.

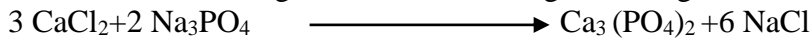
Internal conditioning	External conditioning
Treating the boiler water after feeding it into boiler by adding chemicals to remove scale forming substance is called internal conditioning Ex: carbonate conditioning, phosphate conditioning, calgon conditioning	Treating the boiler water before feeding it into boiler is called external conditioning. Ex: zeolite process, Demineralisation process

14. Distinguish between soft water and demineralised water or Demineralised water is soft water but Soft water is not Demineralised water. Why?

The soft water (produced by Lime soda and zeolite processes) does not contain hardness producing Ca^{2+} and Mg^{2+} ions but it will contain other ions like Na^+ , K^+ , SO_4^{2-} , Cl^- etc.,
 Demineralised water does not contain both anions and cations

15. How is phosphate conditioning carried out?

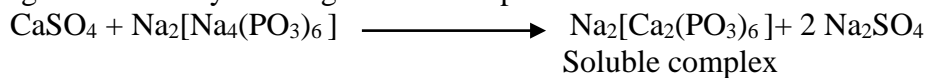
The formation of scale is prevented by adding sodium phosphate (Na_3PO_4) The added phosphate reacts with calcium and magnesium salts forming soft sludge.



This process is suitable for high pressure boilers.

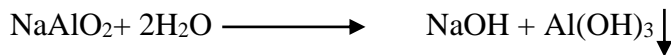
16. Explain the chemical reaction involved in Calgon conditioning. AU-2014

This process involves the addition of sodium hexa meta phosphate in boiler water. It prevents scales and sludge formation by forming soluble complex.

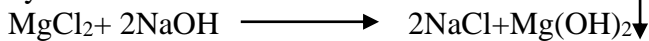


17. How is Sodium aluminate conditioning carried out

It is formation of sludge by adding of sodium aluminate, the sludge is removed by blow down operation.



Sodium aluminate reacts with boiler water (hydrolysis) to produce Sodium hydroxide and aluminium hydroxide



Sodium hydroxide reacts with magnesium chloride to produce magnesium hydroxide

The flocculent precipitate of $\text{Al}(\text{OH})_3$ and $\text{Mg}(\text{OH})_2$ produced inside the boiler are finely suspended and colloidal impurities including oil drops and silica

18. What is desalination?

The process of removing common salt (NaCl) from the water (salt water or brackish water) is known as desalination. It can be carried out by Reverse osmosis (RO) process

19. What is Reverse osmosis?

When two solutions of different concentrations are separated by a semipermeable membrane, If pressure in excess of osmotic pressure is applied on the higher concentrated side, the solvent flow from higher concentration to lower concentration side. This process is called reverse osmosis

20. What are the advantages of reverse osmosis method and limitations?

- i. Low capital cost, easy operating.
- ii. RO method is used for converting sea water into drinking water.
- iii. It removes all types of impurities like non-ionic and colloidal.
- iv. The life time of membrane is high and it can be replaced within few minutes

Limitations

- 1. The water is demineralized. Since most mineral particles (including sodium, calcium, magnesium, magnesium, and iron
- 2. High Hydrostatic pressure should be need for this process.

21. Distinguish between internal conditioning and external conditioning methods of water.

Internal Treatment	External Treatment
It is carried out before feeding into the boiler	It is carried out within the boiler
It is used for high pressure	It is used for Low pressure boiler
Blow down operation is not required	Blow down operation is required

22. Distinguish between carbonate (Temporary hardness) CH and noncarbonated hardness (permanent) NCH

Carbonate (Temporary hardness)CH	Non-carbonate hardness (Permanent) NCH
It is due to bicarbonate of calcium and magnesium	It is due to chloride and sulphate of calcium magnesium
It can be removed by boiling the water	It can not be removed by boiling the water
It is also called as alkaline	It is also called as Non-alkaline
Example: $\text{Ca}(\text{HCO}_3)_2$ $\text{Mg}(\text{HCO}_3)_2$	Example: $\text{CaCl}_2, \text{CaSO}_4$

23. What is mean by internal conditioning of water?

Internal conditioning is the processes which involve the removal of scale forming substance by adding chemicals directly in to the boiler.

24. Why calgon conditioning is better than the phosphate conditioning.

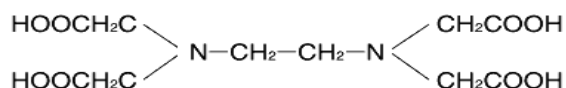
In Calgon conditioning calgon forms highly soluble complex but in phosphate conditioning it give sludge, So periodical disposal of sludge is important in phosphate conditioning but calgon conditioning no problem of disposal

PART- B
16 Marks Questions

1. Explain the estimation of hardness by EDTA method
2. What are the troubles caused by using hard water in boilers? or (Disadvantages of using hard water in boilers)How it can be prevented? (16).
3. Define external conditioning and explain the demineralization of water by ion-exchange process. How exhausted cation and anion exchange resins are regenerated? (10)
4. Describe zeolite process for water treatment.(6)
5. Explain internal conditioning of boiler feed water (8)
6. What is desalination? With a neat diagram describe reverse osmosis in detail.

1. Explain the estimation of hardness by EDTA method. (8)

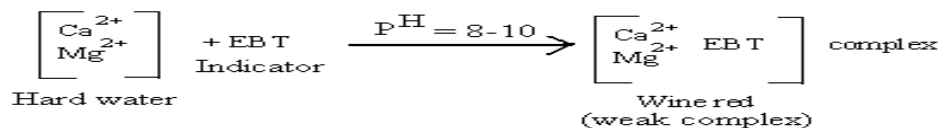
EDTA is Ethylene Diamine Tetra Acetic acid. The structure of EDTA is



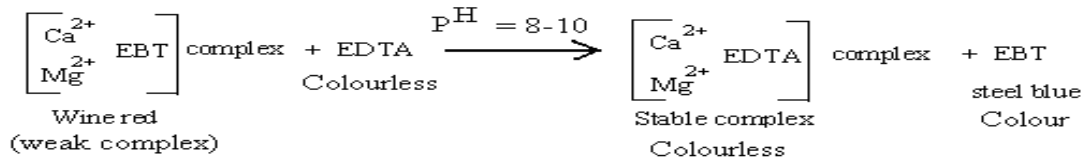
Since, EDTA is insoluble in water; its disodium salt is used as a **sequestering** or **complexing** agent.

Principle:

- 1) The amount of hardness causing ions (Ca^{2+} and Mg^{2+}) can be estimated by titrating the water sample against EDTA.
- 2) Indicator –Eriochrome Black-T (EBT).
- 3) Buffer solution - a mixture of NH_4Cl – NH_4OH is added to maintain the p^{H} at 8-10.
- 4) When the EBT indicator is added to the water sample, it forms wine red coloured weak complex with Ca^{2+} and Mg^{2+} ions.



5) When the wine red solution is titrated against EDTA solution, EDTA replaces EBT and forms stable complex with Ca^{2+} and Mg^{2+} ions.



6) The end point is the change of colour from wine red to steel blue.

Preparation of solutions:

(i) Standard hard water:

1 gm of pure CaCO_3 is dissolved in minimum quantity of HCl and then made up to 1000ml using distilled water.

1ml of standard hard water = 1mg of CaCO_3 equivalent hardness.

(ii) EDTA solution

Dissolve 4g of EDTA or its disodium salt in 1000ml of distilled water.

(iii) EBT indicator solution

Dissolve 0.5g of EBT in 100ml of Ethanol

(iv) Buffer solutions

Dissolve 67.5g NH_4Cl in 570ml NH_4OH and make up to 1000ml using distilled water

	Titration –I: Standardisation of EDTA	Titration –II: Estimation of total hardness	Titration –III: Estimation of Permanent hardness
Burette solution	EDTA	Standardized EDTA	Standardized EDTA
Pipette solution	Std. Hard water (20 ml)	Water Sample (20 ml)	Boiled water (20 ml)
Additional solution	2 ml ammonia buffer ($\text{NH}_4\text{Cl} + \text{NH}_4\text{OH}$)	2 ml ammonia buffer ($\text{NH}_4\text{Cl} + \text{NH}_4\text{OH}$)	2 ml ammonia buffer ($\text{NH}_4\text{Cl} + \text{NH}_4\text{OH}$)
Indicator	EBT (2-3 drops)	EBT (2-3 drops)	EBT (2-3 drops)
End point	Wine red to steel blue	Wine red to steel blue	Wine red to steel blue
			Equivalent weight of $\text{CaCO}_3=50$

Experimental procedure:

(i) Standardization of EDTA

Pipette out 20 ml of standard hard water into clean conical flask. Add 5ml of buffer solution and 2-3 drops of EBT indicator and titrate it against EDTA solution taken in the burette. The end point is the change of colour from wine red to steel blue.

Let the volume of EDTA consumed be V_1 ml.

(ii) Estimation of total hardness of water sample

Pipette out 20 ml of the given hard water sample into a clean conical flask and titrate it against EDTA as before.

Let the volume of EDTA consumed be V_2 ml.

(iii) Estimation of permanent hardness of water sample

Take 100ml of the same hard water sample in a 250ml beaker. Boil it for 15 minutes. During boiling temporary hardness gets removed. Cool and filter the solution and make up to 100ml in a standard flask by adding distilled water.

Pipette out 20ml of the made up solution into a clean conical flask and titrate it against EDTA as before.

Let the volume of EDTA consumed be V_3 ml.

Calculations:

(i) Standardisation of EDTA

$$\begin{aligned} 1\text{ ml of std hard water} &= 1 \text{ mg of CaCO}_3 \\ 20\text{ ml of std hard water} &= 20 \text{ mgs of CaCO}_3 \\ 20\text{ ml of std hard water consumes} &= V_1 \text{ ml of EDTA} \\ V_1\text{ ml of EDTA} &= 20 \text{ mgs of CaCO}_3 \text{ equivalent hardness} \end{aligned}$$

(or)

$$1 \text{ ml of EDTA} = \frac{20}{V_1} \text{ mgs of CaCO}_3 \text{ equivalent hardness}$$

(ii) Estimation of total hardness of water sample

20 ml of the given hard water sample consumes = V_2 ml of EDTA

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

(iii) Estimation of permanent hardness of water sample

20 ml of the same hard water sample after boiling, filtering, etc., consumes } = V_3 ml of EDTA

$$\text{Permanent hardness} = 1000 \times \frac{V_3}{V_1} \text{ ppm}$$

(iv) Temporary hardness

$$\begin{aligned} \text{Temporary hardness} &= \text{Total hardness} - \text{Permanent hardness} \\ &= 1000 \times \frac{V_2}{V_1} - 1000 \times \frac{V_3}{V_1} \\ \text{Temporary hardness} &= \frac{1000}{V_1} (V_2 - V_3) \text{ ppm} \end{aligned}$$

Note: 1000ml of 1M EDTA =100g of CaCO₃
1ml of 1M EDTA =1mg of CaCO₃
1ml of 0.01M EDTA=1mg of CaCO₃
1ml of 0.02N EDTA=1mg of CaCO₃
1ml of 0.025M EDTA=2.5 mg of CaCO₃

2)100ml of a water sample requires 20ml of EDTA for titration.1ml of EDTA solution is equivalent to 1.1mg of CaCO₃. Calculate hardness in ppm

Given:

$$\begin{aligned} 1\text{ ml of EDTA} &= 1.1\text{ mg of CaCO}_3 \\ 100\text{ ml of water sample} &= 20\text{ ml of EDTA} \\ &= 20 \times 1.1\text{ mg of CaCO}_3 \\ &= 22\text{ mg of CaCO}_3 \\ 1000\text{ ml of water sample} &= (22 \div 100) \times 1000 \\ &= 220\text{ mg /lit or ppm} \end{aligned}$$

3) 0.28 gm of CaCO_3 was dissolved in one litre of water using HCl. 100 ml of this water requires 28 ml of EDTA on titration. 100 ml of sample hard water requires 33 ml EDTA on titration the same requires 10 ml EDTA after boiling, cooling and filtering. Calculate the temporary and permanent hardness of water. (8)

Given:

1000 ml of std. hard water contains = 0.28 gms of CaCO_3

Converting into mgs then,

$$\begin{aligned} &= 0.28 \times 1000 \text{ mgs of } \text{CaCO}_3 \text{ (Since } 1\text{gm} = 1000 \text{ mgm)} \\ &= 280 \text{ mgs of } \text{CaCO}_3 \end{aligned}$$

1000 ml of std. hard water = 280 mgs of CaCO_3

\therefore 1 ml of std. hard water = 0.28 mgs of CaCO_3

100 ml std. hard water requires = 28 ml of EDTA

\therefore 28 ml of EDTA = 100×0.28 mgs of CaCO_3 (Since 1 ml std. hard water = 0.28 mg of CaCO_3)

\therefore 1 ml of EDTA = $(100 \times 0.28) \div 28 = 1 \text{ mg of } \text{CaCO}_3$

(i) **Total hardness:**

100 ml sample hard water requires = 33 ml of EDTA
= 33×1 mg of CaCO_3
= 33 mgs of CaCO_3

\therefore 1000 ml of sample hard water = $(33 \div 100) \times 1000$

Total hardness = 330 mgs/Lit or ppm.

(ii) **Permanent hardness:**

100 ml of sample water requires = 10 ml of EDTA
(after boiling, cooling and filtering)
= 10×1 mg of CaCO_3
= 10 mgs of CaCO_3

\therefore 1000 ml of sample hard water = $(10 \div 100) \times 1000$
(after boiling, cooling and filtering)

Permanent hardness = 100 mgs/Lit or ppm.

(iii) **Temporary hardness:**

$\text{Total hardness} = \text{Temporary hardness} + \text{Permanent hardness}$

\therefore Temporary hardness = Total hardness – Permanent hardness
= $330 - 100$

Temporary hardness = 230 mgs/Lit or ppm.

4) Calculate permanent hardness from the following. 500 ml of a water sample is boiled for 1 hr. it is then cooled and filtered. The filtrate is made upto 500 ml again with distilled water. 50 ml of this solution requires 10 ml of N/50 EDTA with EBT-indicator and $\text{NH}_4\text{Cl-NH}_4\text{OH}$ buffer.

Given:

50 ml of water sample after boiling, filtering requires 10 ml of N/50 EDTA

We know that,

1 ml of N/50 EDTA = 1 mg of CaCO_3

\therefore 10 ml of N/50 EDTA \equiv 10 mg of CaCO_3

50 ml of boiled water sample = 10 ml of N/50 EDTA = 10 mg of CaCO_3

1000 ml of the water = $10 \times (100 \div 50)$

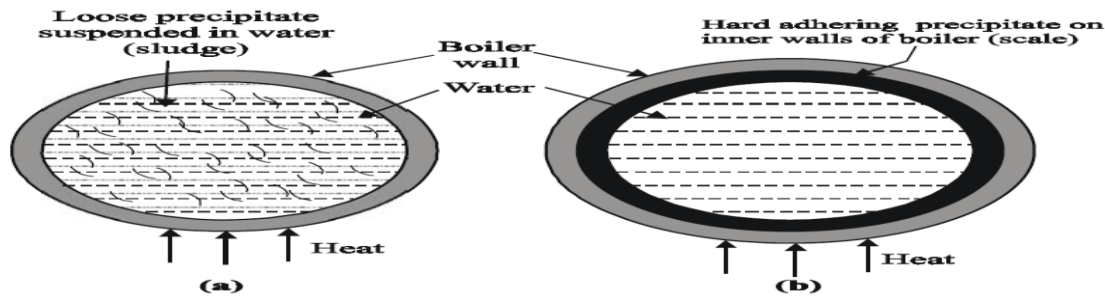
\therefore Permanent hardness = 200 mgs/lit or ppm.

5. What are the troubles caused by using hard water in boilers? or (Disadvantages of using hard water in boilers) How it can be prevented? (16).

The water fed into the boilers for the production of steam is called boiler fed water. If the hard water is directly fed into the boilers the following troubles may arise.

Boiler troubles:

(i) Sludge and scale formation



(a) SLUDGE IN BOILER

(b) SCALE IN BOILER

S.No	Sludge	Scale
1	Sludge is a loose, slimy and non adherent precipitate.	Scale is a hard and adherent coating formed on the inner walls of the boiler
2	It is formed by $MgCl_2$, $MgCO_3$, $MgSO_4$ and $CaCl_2$.	It is formed by $Ca(HCO_3)_2$, $CaSO_4$, $Mg(OH)_2$.
3	<u>Disadvantages of Sludge formation</u> (i) Sludge is poor conductor of heat. (ii) It reduces boiler efficiency.	<u>Disadvantages:</u> (i) Scale act as thermal insulator. (ii) Wastage of fuels. (iii) Decrease in efficiency. (iv) Boiler explosion.
4	<u>Prevention:</u> (i) Sludge formation can be prevented by using softened water	<u>Prevention of Scale formation:</u> (i) Scale formation can be prevented by internal and external conditioning
5	(ii) Sludge formation can be prevented by blow-down' operation	(ii) Scale formation can be prevented by using acids like HCl , H_2SO_4
6	(iii) Blow-down operation is a process of removing a portion of concentrated water by fresh water frequently from the boiler during steam production	(iii) Scale formation can be prevented by scrapping, using wire brush, thermal shocking etc

6. Define external conditioning and explain the demineralization of water by ion-exchange process. How exhausted cation and anion exchange resins are regenerated? (10)

SOFTENING OR CONDITIONING METHODS

The process of removing hardness causing salts from water is known as softening or conditioning of water. There are two methods

I) External conditioning.

- a) Ion-exchange or Demineralisation process.
- b) Zeolite process.

II) Internal conditioning.

DEXTERNAL CONDITIONING:

It involves the removal of hardness producing salt from the water before feeding into the boiler. The external treatment can be done by Ion-exchange or Demineralisation process.

a) Ion-exchange or Demineralisation process:

This process removes almost all the ions (*both anions and cations*) present in the water.

This process is carried out by using ion exchange resins. Resins are long chain, cross linked, insoluble organic polymers with a micro porous structure.

Two types of resins are used. a) Cation exchange resin. b) Anion exchange resin.

a) Cation exchanger:

- * It contains acidic functional groups (-COOH, -SO₃H).
- * It is capable of exchanging their H⁺ ions with other cations.
- * It is represented as RH₂.

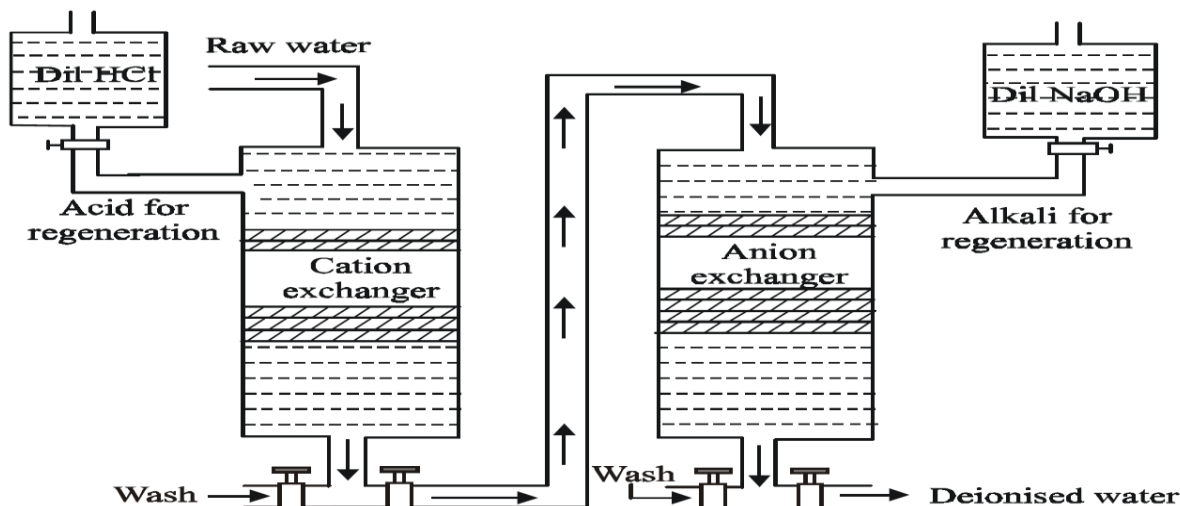
[Example: (i) Sulphonated coal. (ii) Sulphonated polystyrene.]

b) Anion exchanger:

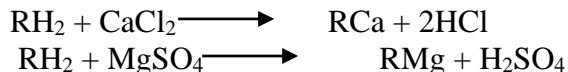
- * It contains Basic functional groups (-NH₂, -OH).
- * It is capable of exchanging their OH⁻ ions with other anions.
- * It is represented as R'(OH)₂.

[Example: (i) Cross linked quarternary ammonium salts. (ii) Urea formaldehyde resin.]

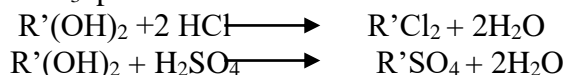
Process:



The hard water is first passed through a cation exchange column. It absorbs all the cations like Ca²⁺, Mg²⁺, Na⁺ and K⁺ present in the water.



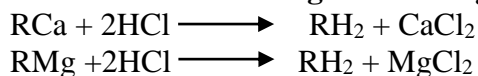
The cation free water is then passed through a anion exchange column. It absorbs all the anions like Cl⁻, SO₄²⁻ and HCO₃⁻ present in water.



The water coming out of the anion exchanger is completely free from both cations and anions. This water is known as demineralised water or deionised water.

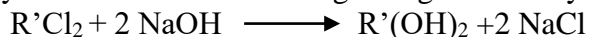
Regeneration of Cation-exchange resin: (CER)

The exhausted **Cation-exchange resin** is regenerated by passing dilute acids like *HCl* or *H₂SO₄*.



Regeneration of anion-exchange resin: (AER)

Similarly exhausted anion-exchange resin is regenerated by passing dilute bases like *NaOH* etc.,



Advantages:

- Highly acidic or alkaline water can be treated by this process.
- The water obtained by this process will have very low hardness (2 ppm)

Disadvantages:

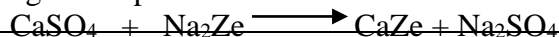
- Turbid water cannot be treated by this method.
- The equipment and chemicals used in this method are costly.

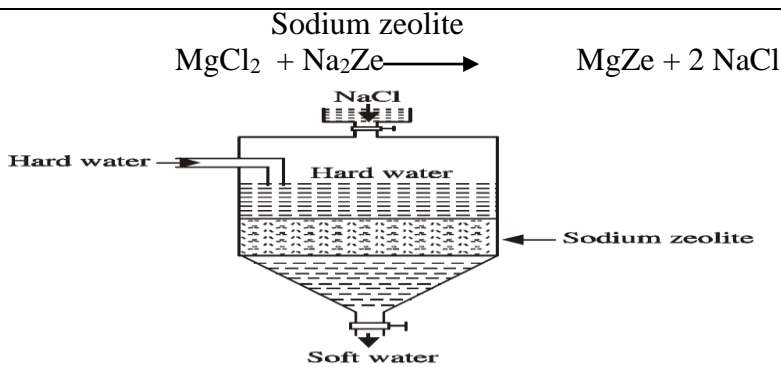
7. Describe zeolite process for water treatment.(6)

Naturally occurring Zeolite is Hydrated Sodium aluminosilicate. The synthetic form of zeolite is called permutit. It is represented as Na₂Ze. It exchanges only cations.

Process:

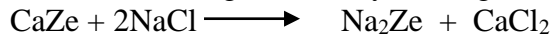
Hard water is passed through sodium zeolite kept in a cylinder. It exchanges Na⁺ ions with Ca²⁺ and Mg²⁺ ions present in the hard water. The various reactions are shown below





Regeneration:

The exhausted zeolite is regenerated by treating with 10% NaCl solution.



Advantages:

- (i) The water obtained by this process will have very low hardness (1~2 ppm)
- (ii) This method is cheap and no sludge is formed.
- (iii) The equipment is compact.
- (iv) Easy operation.

Disadvantages:

- (i) Turbid and acidic water cannot be treated.
- (ii) Water containing Fe, Mn cannot be treated.
- (iii) This process cannot be used for softening the brackish water.

8. Explain internal conditioning of boiler feed water (8)

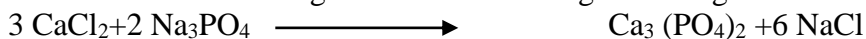
INTERNAL CONDITIONING or BOILER COMPOUNDS

It involves the removal of scale forming substance, by adding chemicals directly into the boiler. There are 4 types,

- a) Phosphate conditioning.
- b) Calgon conditioning.
- c) Colloidal conditioning.
- d) Sodium aluminate conditioning

a) Phosphate conditioning:

The formation of scale is prevented by adding sodium phosphate (Na_3PO_4) the added phosphate reacts with calcium and magnesium salts forming soft sludge.



This process is suitable for high pressure boilers.

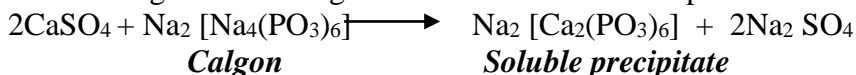
3 types of phosphates are used,

- 1) Na_3PO_4 - Trisodium phosphate – used for acidic water.
- 2) Na_2HPO_4 - Di sodium hydrogen phosphate– used for weakly acidic water.
- 3) NaH_2PO_4 - Sodium dihydrogen phosphate – used for alkaline water.

b) Calgon conditioning:

* Calgon is **sodium hexa meta phosphate**.

* It exchange Ca^{2+} and Mg^{2+} ions in boiler water and prevents scaling.

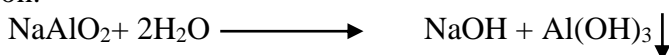


c) Colloidal conditioning:

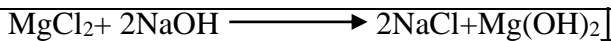
In low pressure boilers the scale formation can be avoided by adding kerosene, agar-agar, gelatin. These colloidal substances get coated over the scale forming particles and convert them into non-adherent, loose precipitate (sludge). It can be removed by blow down operation.

d) Sodium aluminate conditioning:

It is formation of sludge by adding of sodium aluminate, the sludge is removed by blow down operation.



Sodium aluminate reacts with boiler water (hydrolysis) to produce Sodium hydroxide and aluminium hydroxide



Sodium hydroxide reacts with magnesium chloride to produce magnesium hydroxide

The flocculent precipitate of $\text{Al}(\text{OH})_3$ and $\text{Mg}(\text{OH})_2$ produced inside the boiler are finely suspended and colloidal impurities including oil drops and silica

9. What is desalination? With a neat diagram describe reverse osmosis in detail. (8)

Desalination:

The process of removing common salt (NaCl) from water is known as desalination. The water containing dissolved salts with a peculiar salty or brackish taste is called brackish water.

Desalination is carried out by reverse osmosis.

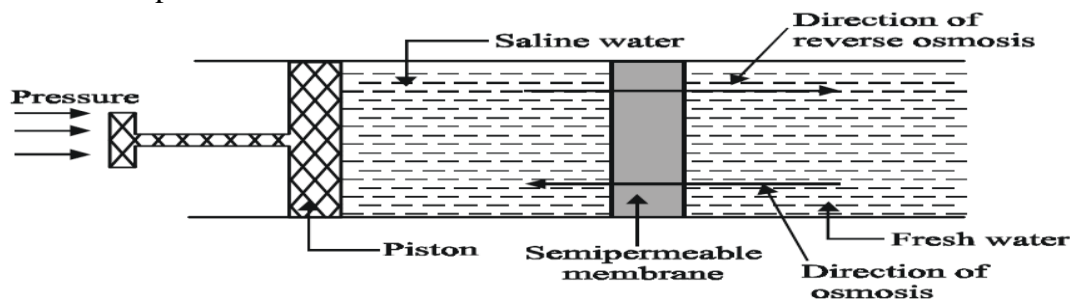
1. Fresh water contains < 1000 ppm of dissolved salts
2. Brackish water contains 1000-35000ppm of dissolved salts
3. Sea water contains > 35000 ppm dissolved salts

Reverse Osmosis (RO):

When two different concentrated solutions are separated by a semi permeable membrane, solvent (water) flows from a region of low concentration to higher concentration. This process is called osmosis. the driving force is osmotic pressure.

Definition:

If the pressure (*hydrostatic pressure*) in excess of osmotic pressure is applied on the higher concentration side solvent flow is reversed i.e ***solvent flows from higher concentration to lower concentration***. This process is called reverse osmosis.



Osmosis: Lower concentration (Fresh water) to Higher concentration (Saline water)

Reverse osmosis: Higher concentration (Saline water) to Lower concentration (Fresh water)

Membranes used:

Cellulose acetate, cellulose butyrate

Advantages:

- (i) Easy operation method and low cost.
- (ii) The life time of the membrane is long and can be easily replaced
- (iii) RO method removes ionic, non-ionic and colloidal particles.
- (iv) Used for converting sea water into drinking water.

Exercise

1. 100ml of a water sample required 20ml of 0.01M EDTA for the titration with EBT indicator. 100ml of the same water sample after boiling and filtering required 10ml of 0.01M EDTA. calculate the total, carbonate and Non carbonate hardness of the sample.
2. In an estimation hardness of water by EDTA titration, 250ml of a water sample required 15ml of 0.025M EDTA solution to get the End point calculate hardness of water
3. 100ml of a water sample required 15ml of 0.01M EDTA for titration using EBT indicator. In another experiment 100ml of the same sample was boiled to remove the CH , the precipitate was removed and the cold

solution required 8ml of 0.01M EDTA using EBT indicator calculate Total Hardness, Permanent Hardness and temporary hardness in terms of mg/lit of CaCO₃

UNIT-II SURFACE CHEMISTRY PART-A

1. Differentiate adsorption and absorption.

ADSORPTION	ABSORPTION
Adsorption is a surface phenomenon	Absorption is a bulk phenomenon
It is a rapid process	It is a slow process
Equilibrium is attained easily	Equilibrium is attained slowly
The concentration of molecule are more on the surface and less in the bulk	But distribution is uniform

2. Mention a few important characteristics of adsorption.

1. Adsorption on surface of a solid is always spontaneous.
2. Adsorption is always accompanied by evolution of heat.
3. Adsorption is accompanied both by decrease in enthalpy and entropy of the system.
4. Adsorption is a selective process.
5. The rate of adsorption depends on temperature.
6. Adsorption is a physical phenomenon, but accompanied by a chemical change.

3. What is physical adsorption? Give an example.

Physical adsorption is the one, in which the adsorbed molecules are held on the surface of the adsorbent by weak physical (or) Vander Waal's forces of attraction. Adsorption of H₂ or O₂ on charcoal

4. What is chemisorptions? Give an example.

Chemical adsorption is the one, in which the adsorbed molecules are held on the surface of the adsorbent by chemical bonds (Covalent bond (or) ionic bond). Adsorption of H₂ on Ni.

5. What is meant by positive and negative adsorption?

POSITIVE ADSORPTION	NEGATIVE ADSORPTION
1. When the solute is adsorbed by an adsorbent it is called positive adsorption.	2. But if the solvent is taken up by the adsorbent it is called negative adsorption.
2. Adsorption of substance from the solution increases with decrease of temperature and increase in concentration of solution. This type of adsorption is known as positive adsorption.	2. Adsorption of substance from the solution decreases with rise of temperature and decrease in concentration of solution.
3. Adsorption of salt (KCl)	3. Adsorption of water

6. Define adsorption isotherm.

Adsorption isotherm is a relationship (or a graph) between magnitudes of adsorption with pressure at constant temperature.

i.e., $\frac{x}{m} = KP^{1/n}$

7. Define Langmuir adsorption isotherm. Postulates

1. Valencies at the surface of adsorbent are not fully satisfied.
2. The adsorbed gas layer on the solid surface is only one molecule thick.
3. The surface of the solid is homogeneous, so the adsorbed layer is uniform all over the adsorbent.
4. There is no interaction between the adjacent adsorbed molecules.

5. The adsorbed gas molecule does not move around on the surface.

8. Define the terms adsorbent and adsorbate with suitable example.

Adsorbate : The substance which is held on the surface of the solid is called the adsorbate
H₂ (gas)

Adsorbent: The solid that takes up a gas or a solute from the solution is called adsorbent
Ni (Solid)

9. Define catalysis and mention its types of catalysis with an example.

1. Homogeneous catalysis 2. Heterogeneous catalysis

Homogeneous catalysis: Homogeneous catalysis is the reaction in which the catalyst as well as the reacting substances are present in the same phase. That is if the reactants are solid (or) liquid (or) gases, the catalysts are also solid (or) liquid (or) gases respectively.

Heterogeneous catalysis: Heterogeneous catalysis is the reaction in which the catalyst as well as the reacting substances are present in the different phases.

10. Define catalyst and types

Catalyst is defined as a substance, which alters (increases or decreases) the rate of a chemical reaction without undergoing any change in amount and chemical composition at the end of the reaction.

POSITIVE CATALYST	NEGATIVE CATALYST
A catalyst, which enhances (increases) the rate of the chemical reaction is called a positive catalyst	A catalyst, which retards (decreases), the rate of the chemical reaction is called a negative catalyst (or) Inhibitors
MnO ₂ in the decomposition of KClO ₃ into KCl and O ₂ .	Alcohol retards the oxidation of chloroform to poisonous phosgene.

11. What are catalytic promoters?

The addition of a small amount of foreign substances increases the activity of the catalyst such substances are called catalytic promoters.

12. What is meant by catalytic poisoning and types?

Catalytic poisoning refers to the partial (or) total deactivation of a catalyst caused by exposure to a range of chemical compounds (or) substance. Thus, substances which destroy the activity of the catalyst are known as catalytic poisons.

1. Temporary poisoning: In this type of catalytic poisoning, the catalyst regains its activity when the substance, responsible for poisoning, is removed from reactants.

2. Permanent poisoning: In this type of catalytic poisoning the catalyst is poisoned permanently and cannot regain its activity even by removing the catalytic poison.

13. Define auto catalyst.

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

14. How an acid –base catalysis is carried out?

A large number of homogeneous catalytic reactions are brought about by acids or bases or both acids and bases. These reactions are called Acid-Base catalysis

Acid catalyst: A reaction, which is catalysed not only by H⁺ (acid) ions, but also all Bronsted acids (Proton donors) cause acid catalysis. H⁺, un dissociated acids (CH₃COOH), cations of weak bases (NH₄⁺) and water (H₃O⁺).

Base catalyst: A reaction, which is catalysed not only by OH⁻ ions (base), but also all Bronsted bases (Proton acceptors) cause base catalysis.

Example: OH⁻, un dissociated bases (NH₄OH), anions of weak acids (CH₃COO⁻) and water (H₂O)

15. How do enzymes act as catalyst?

Enzyme or biological catalysts are complex organic substance of high molecular weight proteins derived from living organisms. They catalyst brought about by enzymes are known as enzyme catalysis .Each enzyme can catalyse a specific reaction.

15. List the factors that affect adsorption.

1. Nature of gases.
2. Nature and surface area of adsorbents.
3. Heats (or) Enthalpy of adsorption.

4. Reversible character of adsorbed gases.
5. Pressure of gas.
6. Temperature of gas.
7. Thickness of adsorbed layer of gas.
8. Activation of adsorbent

PART-B

1. Differentiate physisorption and chemisorptions.
2. Describe the factors that influence adsorption of a gas on a solid.
3. Derive Freundlich's adsorption isotherm and state its limitations.
4. State the postulates and derive Langmuir adsorption isotherm and discuss it with various pressures.
5. Explain contact theory of catalysis or illustrate the role of adsorbents in ion exchange adsorption.
6. Derive the rate of a unimolecular reaction and bimolecular or Langmuir-Hinshelwood mechanism in a surface reaction..
7. Derive Michaelis –Menten equation from Enzyme and Substrate?
8. Outline the role of activated carbon in pollution abatement of water
9. Derive kinetics of acid basis catalysis of 1.First mechanism 2.second mechanism

Definitions:

1) Adsorption:

The Phenomenon of concentration of a gas or liquid molecules on a solid surface is called Adsorption.

The adsorption of a gas molecules solid surface is also called occlusion

2) Adsorbate:

The substance which is adsorbed a solid surface is called Adsorbate

3) Adsorbent:

The solid that adsorbs a gas or a solute on its surface is called Adsorbent

4) Adsorption:

the process in which a substance is uniformly distributed kthroughout the body of the solid or liquid is called Absorption.

5) Sorption:

The process in which both adsorption and absorption occur simultaneously is called sorption.

Distinction between Adsorption & Absorption

Adsorption	Absorption
1) Adsorption is a surface phenomenon	Absorption is a bulk phenomenon
2) It is a rapid process	It is a slow process
3) Equilibrium is attained easily	Equilibrium is attained slowly
4) The concentration of molecules are more on the surface and less in the bulk	Distribution of molecules is uniform throughout the body

Classification of Adsorption:

Adsorption is classified into two types namely

- 1) Physical Adsorption (or) physisorption
- 2) Chemical Adsorption (or) chemisorption

1) Physical Adsorption:

The adsorption process in which the adsorbed molecules are held on the surface of the adsorbent by weak physical (or) van der waals forces pf attraction is called physical adsorption (or) Physisorption.

Eg: Adsorption of H₂ or O₂ on charcoal

2) Chemical Adsorption:

The adsorption process in which the adsorbed molecules are held on the surface of the adsorbent by strong chemical bonds like covalent or jonic bond is called chemical adsorption (or) chemisorption.

Eg: Adsorption of H₂ on Ni surface

Hydrogen molecule is first adsorbed by van der Waals forces and then dissociated into hydrogen atoms which are then chemisorbed on nickel surface.

Difference between Physisorption and Chemisorption

Physisorption	Chemisorption
1) It involves weak van der Waals forces	It involves strong chemical bond formation
2) Heat of adsorption is low (0-40 kJ/mole)	Heat of adsorption is high (40-400 kJ/mole)
3) Adsorption is totally reversible	Adsorption is irreversible
4) Adsorption decreases with increase of temperature.	Adsorption increases with increase of temperature.
5) The rate of adsorption increases with increase of pressure and concentration	The rate of adsorption decreases with increase of pressure and concentration
6) Multilayer adsorption occurs	Monolayer adsorption occurs
7) Surface compound is not formed	Surface compound is formed
8) Equilibrium is attained rapidly	Equilibrium is attained slowly
9) It is not specific in nature	It is highly specific in nature
10) It involves very small activation energy	It involves high activation energy

Characteristics of Adsorption:

- 1) Adsorption on the surface of a solid is always a spontaneous process.
- 2) Adsorption is always accompanied by the evolution of heat.
- 3) Adsorption is accompanied by decrease in enthalpy and entropy of the system.
- 4) Adsorption is a selective process.
- 5) The rate of adsorption depends on the temperature.
- 6) Adsorption is specific and depends on the nature of the adsorbent and adsorbate.
- 7) Adsorption is a physical process but accompanied by a chemical change.

Adsorption of Gases on solids:

All solids adsorb gases to some extent. The magnitude of adsorption of gases by solids depends on the following factors:

- 1) Nature of the gases
- 2) Nature and surface area of adsorbent
- 3) Heat (or) Enthalpy of adsorption
- 4) Reversible character of adsorbed gases
- 5) Pressure of the gas.
- 6) Temperature of the gas
- 7) Thickness of adsorbed gas layer.
- 8) Activation of the adsorbent.

Factors that influence Adsorption of gases on solids:

- 1) Nature of the gas:

The amount of a gas adsorbed on a solid surface depends on the nature of the gas.

Eg: The easily liquefiable gases like HCl, NH₃, SO₂, Cl₂, etc. are adsorbed more easily than the permanent gases like H₂, N₂, O₂, etc.

Reasons:

- 1) Van der Waals forces:

The easily liquefiable gases possess greater van der Waals forces than the permanent gases. Therefore, they are adsorbed more easily.

- 2) Critical temperature:

The gases which possess more critical temperature are liquefied easily and adsorbed more readily.

[Critical temperature – The maximum temperature above which a gas cannot be liquefied]

Gases	Critical temp (K)	Amount of gas adsorbed (ml)
H ₂	33	4.5
N ₂	126	8.0
CO ₂	304	48
NH ₃	406	180

2) Nature and surface area of adsorbents:

The extent of adsorption depends on the surface area. Thus

- i) The greater the surface area, the greater will be the adsorption.
- ii) The layer the pores on the adsorbent, the layer will be the adsorption

Ex:

Charcoal and silica gel These adsorbents possess large surface area due to their highly porous structure.

3) Heat (or) Enthalpy of adsorption:

Adsorption is an exothermic process and it proceeds with the evolution of heat.

The heat energy liberated when one mole of a gas is adsorbed on a solid surface is called the heat of adsorption.

In a physical adsorption, the heat of adsorption is small (5k cal/mole), because it involves a very weak van der waal's forces of attraction between the gas molecules and the solid surfaces.

In a chemical adsorption the heat of adsorption is large (100k cal/mole), because it involves a strong forces of attraction due to chemical bond formation.

4) Reversible character of adsorbed gases:

Physical adsorption is a reversible process. The gas adsorbed on a solid can be released or desorbed under the reverse conditions of temperature and pressure.

Gas + solid \rightarrow Gas/Solid + Heat

Chemical adsorption is an irreversible process, because of the formation of a surface compound

5) Effect of pressure of the gas:

A dynamic equilibrium exists between the gas adsorbed on solid and the gas in contact with the solid.

\therefore An increase of pressure increases the adsorption and a decrease of pressure will decrease the adsorption.

Increase pressure
 Gas in contact with solid \rightarrow Adsorbed gas on solid
 Decrease of pressure

6) Effect of temperature of the the gas:

A physical adsorption of a gas occurs rapidly at lower temperature and decrease with increase of temperature. This is shown in the graph:

A Chemical adsorption of a gas increases with increase of temperature and then decreases. This is shown in the graph:

7) Thickness of the adsorbed gas layer gas:

According to Longmuir

- i) In physisorption, the adsorbed gas forms a layer of one molecule thickness at a low pressure. But at a high pressure, a layer of multimolecular thickness is formed.
- ii) In chemisorptions, the adsorbed gas forms a one layer molecule thickness only because chemical combination occurs directly with the surface of the adsorbent.

8) Activation of the adsorbent:

Activation of the adsorbent increases as the surface area of the adsorbent increases.

- i) Activation of the adsorbent can be done by increasing the effective surface area of the adsorbent:
 - a) by grinding the solid adsorbent into a fine particles.
 - b) by heating the solid adsorbent in hot steam to open its pores.
- ii) Creating rough surfaces
 - a) by mechanical rubbing on the solid adsorbents.
 - b) by doing some chemical reaction on the solid adsorbents.

Adsorption of solutes from solutions:

An adsorbent can adsorb certain solutes or substances from the solution in the ways:

1) Adsorbent adsorbs dissolved solutes from solutions

Ex: Activated charcoal

- i) It adsorbs the colouring materials present in sugar solution
- ii) It adsorbs Acetic acid and oxalic acid present in water.
- iii) It adsorbs the ammonia from a solution of ammonia and phenolphthalein

2) Adsorbent adsorbs a particular substance in preference to other substances from a solution

Eg: 1 Charcoal – it absorbs non-electrolytes more readily than the electrolytes from the solution containing both.

Eg: 2 Alumina- It absorbs electrolytes more readily than the non-electrolytes from the solution containing both

Factors that influence the adsorption of solutes from solutions:

The factors influencing the adsorption of solutes from the solutions are

- 1) Effect of temperature and concentration.
- 2) Nature of solute adsorbed.
- 3) Effect of surface area.

1) Effect of temperature and concentration:

The extent of adsorption of a substance from a solution depends on the temperature and concentration of the solution.

Freundlich adsorption isotherm equation can explain the effect of temp and concentration. A constant temp $x/m = KP^{1/n}$ Freundlich equation The equilibrium pressure 'P' is replaced by equilibrium concentration 'C' of the solute then

$$x/m = KC^{1/n}$$

Taking log on both sides, we get

$$\log x/m = \log K + 1/n \log C$$

Where,

K and n = Constants

x = mass of adsorbate

m = mass of adsorbent

If a graph is drawn between $\log x/m$ and $\log C$, a straight line is obtained for small ranges of concentration.

when an adsorbent (solute) is dropped into a solution, it may adsorb either the solute or the solvent.

i) Positive adsorption:

Ex: From the concentrated solution of KCl, charcoal adsorbs KCl rather than water, thereby decreasing the concentration of KCl in the solution. This type of adsorption is called positive adsorption.

ii) Negative adsorption:

When a solvent is adsorbed by the adsorbent, it is called negative adsorption.

Ex: From the dilute solution of KCl, charcoal adsorbs water, thereby increasing the concentration of KCl in the solution. This type of adsorption is called Negative adsorption

2) Nature of solute adsorbed:

When the molecular weight of solute is high, the greater will be the adsorption.

3) Effect of surface Area;

When the surface area of the adsorbent is larger, the greater will be the adsorption.

Adsorption Isotherm

Adsorption Isotherm is a graph which the magnitude of adsorption with pressure at constant temperature.

At constant temp, $x/m = K P^{1/n}$

Where, X = Mass of adsorbate

m = Mass of adsorbent

x/m = Extent of adsorption

p = Pressure

k & n = Constant

The graph indicates that

- i) The extent of adsorption, x/m , increases with the increase of pressure and becomes maximum at P_s , the saturation pressure.
 - ii) At P_s , the rate of adsorption becomes equal to the rate of desorption and a dynamic equilibrium is attained.
- Free Gases → Gas adsorbed on solid
- ii) Further increase of pressure does not alter the equilibrium.

Freundlich's Adsorption Isotherm:

The relationship between the magnitude of adsorption (x/m) and pressure (P) can be mathematically expressed by an empirical formula known as Freundlich adsorption isotherm.

$$x/m = K P^{1/n} \text{ at constant Temp}$$

$$= \log x/m = \log K + 1/n \log P$$

Derivation of Freundlich's Adsorption Isotherm:

The equation of Freundlich adsorption isotherm can be derived from the result observed from the following graph:

i) At low pressure, adsorption increases with pressure.

$$x/m \propto P$$

$$\text{i.e., } x/m = K P$$

ii) At high pressure, adsorption is almost constant

$$x/m = \text{constant (or)} x/m = K P^0$$

iii) At intermediate or normal pressure adsorption depends on 0 to 1 power of pressure. i.e., a fraction of power of pressure. The graph does not give a straight line

$$x/m \propto P^{1/n}$$

$$x/m = K P^{1/n}$$

Where, n = whole number.

The above equation is known as Freundlich's adsorption isotherm.

Taking log on both sides, the equation becomes

$$\log x/m = \log K + 1/n \log P$$

A graph of $\log x/m$ Vs $\log P$ gives a straight line with a slope of $1/n$ and an intercept of $\log K$

Limitations of Freundlich's adsorption isotherm:

- 1) Freundlich's equation is purely empirical and has no theoretical basis.
- 2) The equation is valid only upto a certain pressure and becomes invalid at high pressures.
- 3) The constants K and n are temperature dependents, because they vary with temperature.
- 4) The equation fails when the concentration of adsorbate is very high.

Langmuir's Adsorption Isotherm:

Langmuir derived an equation based on certain theoretical assumptions. The assumptions of Langmuir's theory are

- 1) Valencies at the surface of adsorbent are not fully satisfied.
- 2) The adsorbed gas layer on the solid surface is only one molecule thickness.
- 3) The surface of the adsorbent is homogeneous and hence the adsorbed layer is uniform throughout the surface of the adsorbent.
- 4) There is no interaction between the adjacent adsorbed molecules.
- 5) The adsorbed gas molecules do not move around on the surface of the adsorbent.

Derivation of Langmuir's Adsorption Isotherm:

According to Langmuir's assumptions, when the gas molecules strike a solid surface, some of the molecules adsorb and some are desorbed. \therefore A dynamic equilibrium is established between the adsorption and desorption.

Let 'A' is a gas molecule and 'M' is the surface then,

Let,

Fraction of the total surface covered by adsorbed molecule = Q

Fraction of uncovered area = (1-Q)

\therefore The rate of desorption is proportional to the number of adsorbed molecules = $R_d \propto Q$

$$\therefore R_d = K_d Q$$

Where, K_d = Rate constant of desorption

The rate of adsorption is proportional to the available uncovered area = $R_a \propto (1-Q) P$

$$\therefore R_a = K_a (1-Q) P$$

Where, $K_a \Rightarrow$ Rate constant for adsorption

\therefore At equilibrium, Rate of desorption = Rate of adsorption

$$K_d Q = K_a (1-Q) P$$

$$K_d Q = K_a P - K_a Q P$$

$$K_d Q + K_a Q P = K_a P$$

$$Q (K_d + K_a P) = K_a P$$

$$Q = \frac{K_a P}{K_d + K_a P} \longrightarrow 1$$

Dividing eq 1 by K_d , it becomes

$$Q = \frac{(K_a/K_d) P}{1 + (K_a/K_d) P}$$

$$\therefore Q = \frac{KP}{1 + KP} \longrightarrow 2$$

Where, $K_a/K_d = K$ = equilibrium constant called Adsorption coefficient.

But, the amount of gas adsorbed per gram of the adsorbent, x , is proportional to Q .

i.e, $X \propto Q \longrightarrow 3$

Comparing Eq 2 \propto Eq 3, we get

$$X \propto \frac{KP}{1 + KP}$$

$$\therefore X = K^1 \frac{KP}{1 + KP} \longrightarrow 4$$

Where, K^1 is a new constant. This equation is known as Langmuir adsorption isotherm. It gives the relationship between the amount of gas adsorbed and the pressure of the gas (P) at constant temperature.

Langmuir Adsorption Isotherm under different conditions

The Langmuir's equation is

$$X = \frac{K^1 KP}{1 + KP}$$

i.e, $1 + KP = \frac{K^1 KP}{X}$

Divide by $K^1 K$ it becomes

$$\frac{1}{K^1 K} + \frac{KP}{K^1 K} = \frac{P}{X}$$

$$\text{i.e, } \frac{1}{K^1 K} + \frac{K}{K^1 K} P = \frac{P}{X} \longrightarrow 5$$

The above eq 5 is similar to an equation for a straight line, i.e $y = mx + c$

If a graph is drawn between P/X vs P , a straight line is obtained with a slope $K/K^1 K$ and an intercept $1/K^1 K$

\therefore This equation is found to be valid in all cases.

Case1: At low pressure:

If the pressure P is very low, then $K/K^1 K P$ term becomes negligible

i.e, $\frac{1}{K^1 K} \gg \frac{K}{K^1 K} P$

Hence, the eq 5 becomes,

$$\frac{1}{K^1 K} = \frac{P}{X} \text{ or } X = PK^1 K$$

i.e, $X \propto P \longrightarrow 6$

i.e, the amount of adsorption per unit mass of adsorbent X is directly proportional to the P at a low pressure

Case 2: At high pressure:

If the pressure, P is high, then $\frac{1}{K^1 K}$ term is negligible.

i.e, $\frac{K}{K^1 K} P \gg \frac{1}{K^1 K}$

Hence, the eq, 5 becomes

$$\frac{K}{K^1 K} P = \frac{P}{X}$$

$$\therefore X = P \times \frac{K^1}{P K} \times K$$

$$X = K^1 (\text{Constant})$$

(or) $x = K^1 P^0 \longrightarrow 7$

i.e, the amount of adsorption is independence of pressure of the gas. This is because the surface is completely saturated with gas molecules at high pressure.

Case:3 At intermediate (or) Normal pressure:

If the pressure, P is normal (intermediate), then the eq 7 becomes,

$$X = K^1 P^n \longrightarrow 7$$

Where n lies between 0 and 1

The eq 8 is called Freundlich's adsorption isotherm at an intermediate pressure.

Limitations:

- 1) Langmuir's adsorption isotherm holds good at low pressure
- 2) It fails at high pressure.

1) Activated charcoal:

Charcoal which does not contain any adsorbed gases is called activated charcoal. It is used

- a) To adsorb the toxic gases in gas masks.
- b) for removing colouring matters from sugar solution.
- c) for decolouration of vinegar.

2) Silica gel and Alumina gel:

These adsorbents are used

- i) For removing moisture
- ii) For controlling humidities of rooms
- iii) For separating different pigments from a mixture.
- iv) In chromatographic separation processes.

3) Stearic acid:

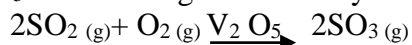
Stearic acid is sprayed on the water surface in lakes and reservoirs during summers. The adsorbed stearic acid on the surface minimizes the evaporation of water.

4) Mordants:

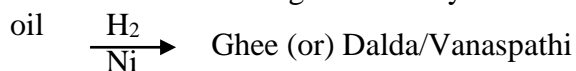
Mordants are used in dyeing industries to adsorb the colouring matter without affecting the fabrics.

5) Heterogeneous Catalysis:

- 1) V_2O_5 is a heterogeneous catalyst used in the manufacture of sulphuric acid by contact process.



- 2) Nickel is used as a heterogeneous catalyst in the hydrogenation of oils.



6) Fuller's earth:

It is used as an adsorbent for refining of petroleum and vegetable oils.

7) Arsenic Poisoning:

Colloidal ferric hydroxide is used to adsorb arsenic poison from the body and is removed by vomiting.

8) Measurement of surface area:

Surface area of powders and rough surfaces can be measured using adsorption measurements.

9) Lake test for Al^{3+} :

It is based on the adsorption of litmus colour by $Al(OH)_3$ precipitate lakes.

10) Ion-exchange resins:

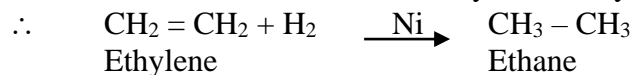
Hard water is softened by adsorption process using suitable ion-exchange resins.

Role of Adsorbents in catalysis (OR) Adsorption theory of catalysis/ contact theory

1) Action of Heterogeneous catalyst:

The catalyst and the reactants are in different phases in heterogeneous catalytic process.

Ex: Nickel Powder is used as a catalyst in the hydrogenation of ethylene to give ethane.



Mechanism of the heterogeneous catalysis involves the following steps:

Step (i): Adsorption of reactant molecules

The surface of the solid catalyst possesses a large number of active centres which adsorb the reactant molecules either by physical or chemical adsorptions.

Heat of adsorption produced during the chemisorption provides the necessary activation energy for the adsorption reaction.

Step (ii) Formation of Activated complex:

The adsorbed molecules which are adjacent to one another join to form an unstable intermediate.

Step (iii) Decomposition of Activated complex is the decomposed to give the products which are bound to the surface of the catalyst by partial chemical bonds.

Step (iv) Desorption of products

Finally the stable products are released from the catalyst.

Ex: Hydrogenation of ethylene in presence Ni catalyst.



Mechanism:

2) Finely divided state of catalyst is more efficient:

When a catalyst is finely divided into minute particles, the surface area of the catalyst is increased. ∴ The free valencies or active centres are increased, thereby increasing the activity of the catalyst.

3) Enhanced activity of a rough surfaced catalyst:

The rough surface of a catalyst generally has cracks, peaks and corners etc. Therefore, it has a large number of active centres which enhance the activity of the catalyst.

4) Action of promoters:

The substance which increases the activity of a catalyst is called promoter.

Explanation:

1) Promoters change the space lattice of the catalyst:

Promoters increase the space lattice of the catalyst. ∴ The adsorbed molecules are further weakened and cleaved and hence the reaction occurs fastly.

Ex: Molybdenum is used as a promoter in the hydrogenation of Ni catalyst.

2) Promoters increase the peaks cracks:

Promoters increase the peaks and cracks on the surface of the catalyst

5) Action of catalytic poisons:

A substance which retards the activity of a catalyst is known as catalytic poison.

Explanation:

Preferential adsorption of catalytic poisons:

Poisons:

The active centres of the catalyst are reduced by the preferential adsorption of catalytic poisons and therefore the activity of the catalyst is retarded.

6) Specific action of the catalyst:

The adsorption process depends on the nature of both the catalyst and the reactants. Different types of catalyst have different affinities for the same reactants. Therefore, the action of a catalyst is highly specific.

Role of adsorbents in Ion-Exchange Adsorption:

The process in which the ion-exchange resins exchange their own ions with another like is called ion-exchange adsorption.

Ion-exchange resins are of two types namely

i) Cation – exchange resins/ cation exchangers

ii) Anion – exchange resins/ Anion exchanger.

i) Cation – exchange resins:

Resins which have acidic functional groups like – COOH, -SO₃H can exchange their H⁺ ions with other cations.

Ex: Sulphonated coals, sulphonated polystyrene.

R-COOH, R-SO₃H.

ii) Anion – exchange resins:

Resins which have basic functional groups like –NH₂, -OH can exchange their anions with other anions.

Ex: 1) Urea – formaldehyde resin

⊕

2) Cross-linked quaternary ammonium salts. R₄ NOH, R-OH, R-NH₂.

Application of ion-exchange adsorption:

1) Ion-exchange process of demineralization water:

“The removal of all cations and anions from water is known as demineralization”

The instrument consists of the vertical columns-one of which contains cation-exchange resins and the other contains anion exchange resins.

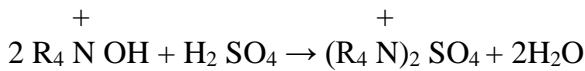
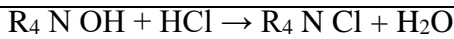
The hardwater is first passed through the column containing cation exchange resins which absorb all the cations like Na⁺, K⁺ & Ca²⁺ & Mg²⁺ present in the hardwater.

R - COOH + NaCl → R- COONa + HCl.

2R-COOH + CaCl₂ → (R-COO)₂ Ca + 2HCl

2R - SO₃H + MgSO₄ → (R-SO₃)₂ Mg + H₂SO₄.

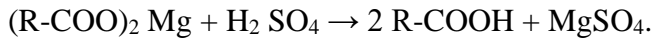
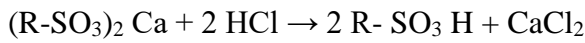
The action free water is then passed through another column which contains anion exchange resins which absorb all the anions like HCO₃²⁻, Cl⁻ and SO₄⁻ present in the water.



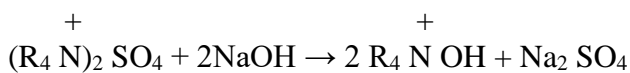
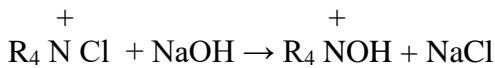
The water coming out of the second column is totally free from all types of cations and anions. This water is known as demineralised water (or) deionised water.

Regeneration of the resins:

The cation – exchange resin is regenerated by passing a dilute solution of HCl or H₂ SO₄ through column.



The anion exchange resin is regenerated by passing a dilute solution of NaOH through the column.



2) Zeolite process of softening of water:

Refer zeolite or permutit process in Water Technology Chapter.

3) Electrical demineralization of water:

Ion-exchange resins which are supported on fibre or paper act as membranes called ion-selective membranes.

Process:

The cation selective membrane permits only cations to pass through it and the anion selective membrane permits only anions to pass through it. The rate of diffusion of ions is increased by passing electric current through the electrodes kept near the membranes. The water in the middle compartment becomes free from all types of ions.

4) Medical applications of ion-exchangers:

1) A suitable ion-exchanger is admitted to a patient to remove the excess sodium salt from the body fluids.

2) A weak basic anion-exchanger can be admitted to remove the excess acid (or) acidity from the stomach.

Pollution Abatement of water & Air by Activated carbon:

Abatement ⇒ Making less

Activated carbon is mostly used as an adsorbent in pollution abatement of waste water and air.

Because, a large surface area per unit mass is available in the granular and powdered form of activated carbon.

Treatment of polluted water and Air:

Polluted water and air can be treated by the following two types of activated carbons:

1) Granular activated carbon (GAL)

2) Powdered activated carbon (PAC)

1) By using Granular Activated carbon:

Granular Activated carbon is filled as fixed – bed in columns which are called fixed-bed activated carbon contactors. different types of such contactor are used in the treatment of polluted water and air. Two important contactors are

a) Down –flow fixed-bed carbon contactors

b) Up-flow fixed-bed carbon contactors.

a) Down-flow fixed-bed carbon contactors

Down-flow fixed –bed carbon contactors consist of two or three vertical columns are operated in series or in a parallel as shown below:

The polluted water or air is applied to the top of the column and withdrawn at the bottom. The granular activated carbon is kept in place with an under drain system at the bottom of the column. Provisions for surface washing and back washing are also provided inside the column in order to remove the accumulated waste materials within the carbon column.

Advantage:

1) Adsorption of organic matters and filtration suspended solids are accompanied in a single step.

Disadvantage:

1) Down-flow filters require frequent back washing due to the accumulation of the suspended solids on the surface of the carbon column or contactors.

~~b) up-flow fixed-carbon contactors:~~

The polluted water or air applied from the bottom of the column as shown below:

Advantage:

The carbon adsorbs the organic matters. As a result, the density of the carbon particles increases and becomes heavier and moves downward in the column.

Disadvantage:

The water collected from the up-flow columns is found to have more fine carbon particles. This is due to the bed expansion which allows the fine carbon particles to pass through.

2) By using powdered Activated carbon (PAL):

Powdered activated carbon is directly added to the polluted primary effluent water coming out of the various biological processes.

The effluent coming out of the plant is mixed with powdered activated carbon and a polyelectrolyte in a contact-aeration tank. It is then allowed to stand in the clarification tank for sometime. The carbon particles are settled down at the bottom of the tank. The poly electrolyte acts as a coagulant and makes the fine carbon particles to be settled.

The spent carbon particles are then regenerated by passing through the regenerating column and reused again in the process. Finally, the water is filtered by passing through the filtration column to give the pure treated water.

UNIT-III – PHASE RULE & ALLOYS

PART – A

1. Define phase (P) with an example

Phase is defined as, “any homogeneous physically distinct and mechanically separable portion of a system which is separated from the other part of the system by definite boundaries”.

A water system consisting of three phases: $\text{Ice}_{(s)} \rightleftharpoons \text{Water}_{(l)} \rightleftharpoons \text{Vapour}_{(g)}$

2. What is component (C)? Give an example.

Component is defined as, “the smallest number of independently variable constituents (Concentration), by means of which the composition of each phase can be expressed in the form of a chemical equation”.

A water system consisting of three phases: $\text{Ice}_{(s)} \rightleftharpoons \text{Water}_{(l)} \rightleftharpoons \text{Vapour}_{(g)}$

The composition of all the three phases is H_2O . Hence, the number of component is one.

3. What is meant by degree of freedom (F)?

Degree of freedom is defined as, “the minimum number of independent variable factors such as temperature, pressure and composition of the phases, which must be fixed in order to define the system completely.

$$F = C - P + 2$$

(A system having 1, 2, 3 or 0 degrees of freedom is called as univariant, bivariant, trivariant and non variant respectively).

4. How many phases and components are there in following systems?

- $\text{CaCO}_{3(s)} \rightleftharpoons \text{CaO}_{(s)} + \text{CO}_{2(g)}$
- $\text{NH}_4\text{Cl}_{(s)} \rightleftharpoons \text{NH}_{3(g)} + \text{HCl}_{(g)}$
- $\text{MgCO}_{3(s)} \rightleftharpoons \text{MgO}_{(s)} + \text{CO}_{2(g)}$
- $\text{PCl}_{5(s)} \rightleftharpoons \text{PCl}_{3(g)} + \text{Cl}_{2(g)}$ at 50°C

- $P=3; C=2; F=C-P+2=2-3+2; \mathbf{F=1 \text{ Univariant}}$
- $P=2; C=1; F=C-P+2=1-2+2, \mathbf{F=1 \text{ Univariant}}$
- $P=3; C=2; F=C-P+2=2-3+2, \mathbf{F=1 \text{ Univariant}}$
- $P=2; C=2; F=C-P+2=2-2+2, \mathbf{F=2 \text{ Bivariant}}$

5. What is phase diagram? What are its uses?

Phase diagram is a graph obtained by plotting one degree of freedom against another.

Ex: (i) One component (P-T diagram):

If the phase diagram is plotted between temperature and pressure. It is used to one component system.

(ii) Two Components (T-C diagram):

If the phase diagram is plotted between temperature and concentration. It is used to two component system.

Uses: It is possible to predict from the phase diagram whether an eutectic alloy or a solid solution is formed on cooling a homogeneous liquid containing mixture of two metals.

6. Define phase rule.

Phase rule is defined as The equilibrium is any number of phase influenced only by temperature, Pressure and concentration but not influenced magnetic electrical and gravity, then the number of degree of freedom (F) of a system related to number of component(C) and number of phase (P) following phase rule equation.

$$\mathbf{F = C - P + 2}$$

Where F= number of degree of freedom

C= number of components

P= number of phases in an equilibrium system

7. State reduced phase rule (Or) condensed phase rule.

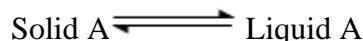
The system in which only the solid and liquid phases are considered and the gas phase is ignored is called a condensed system. Since the pressure is kept constant, the phase rule becomes

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

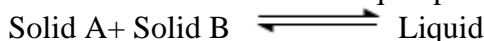
This equation is called reduced phase rule or condensed phase rule.

8. Differentiate melting point, eutectic point and triple point.

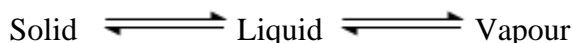
Melting point: It is the temperature at which the solid and liquid phases, having the same composition, are in equilibrium.



Eutectic Point: It is the temperature at which two solids and a liquid phase are in equilibrium.

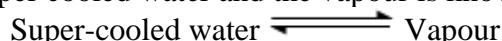


Triple point: It is temperature at which three phases are in equilibrium.



9. What is metastable equilibrium?

Sometimes water can be cooled below 0°C without the formation of Ice. This water is super cooled water. The Equilibrium between super cooled water and the vapour is known as Metastable Equilibrium.



10. Define an alloy.

Alloy is a the homogenous solid solution of two or more different element, one of which atleast one is metal. Alloys containing mercury is called amalgum.

e.g.Brass(Cu+Zn), Bronze (Cu+Sn)

11. What is the significance of alloying?

- (i) To increase the hardness of the metal
- (ii) To lower the melting points of the metal
- (iii) To resist the corrosion of the metal
- (iv) To modify chemical activity of the metal
- (v) To modify the colour of the metal
- (vi) To get good casting of metal

12. What are the properties or objectives of alloys?

- (i) To increase the hardness of the metal
- (ii) To lower the melting points of the metal
- (iii) To resist the corrosion and abrasion of the metal
- (iv) To lower electrical conductivity.
- (v) To increase ductictility, machinability and shock resistance.
- (vi) To increase toughness.
- (vii) To remove internal stress.
- (viii) To improve magnetic and electrical properties
- (ix) To refine grain structure
- (x) To remove imprisoned trapped gases
- (xi) To Improve fatigue and corrosion resistance

13. Define heat treatment of alloys

The heat treatment of an alloy is defined as “the process of heating and cooling of solid steel article under carefully controlled conditions”

14. With an example discuss the types of alloys.

There are two types of alloys:

- i) Ferrous alloys: (i) Nichrome (ii) Stainless steel
- (ii) Non-ferrous alloys: (i) Brass, (ii) Bronze

15. Give the composition and uses of Nichrome.

It is an alloy of nickel, chromium and Iron. Its composition is

Metal	Percentage (%)
-------	----------------

Nickel	60
Chromium	12
Iron	26
Manganese	2

Uses:

1. They are used in making furnace heating coils.
2. They are used as heating elements in electric irons, stoves and kettles.
3. They find use in gas turbines, aero engine valves, retorts, annealing boxes.

16. What is 18/8 stainless steel? What are its properties?

- i) 18/8 stainless steel contains 18% Cr and 8% Ni.
- ii) It is the most widely used stainless steel

Properties:

- (i) It shows maximum resistance to corrosion
- (ii) Corrosion resistance can be increased by adding little quantity of Mo.

Uses: Used in making utensils, sinks, dental and surgical instruments

Part-B

1. State phase rule and explain the terms involved in it. (2+2+2+2 marks)
2. Draw and explain the phase diagram of one component system or water system or application of Phase rule to component system.
3. What is reduced phase rule? Explain lead-silver system or binary alloy system or simple eutectic system in detail and application of peritectic processes.
4. Explain thermal analysis and cooling curves
5. Explain the types of heat treatment of alloys or steel. (8)
6. What are ferrous alloys? Explain the composition, properties and uses of important ferrous alloys.

1.State phase rule and explain the terms involved in it. (2+2+2+2 marks)

Phase rule:

Phase rule is defined as Phase rule is defined as The equilibrium is any number of phase influenced only by temperature, Pressure and concentration but not influenced magnetic electrical and gravity, then the number of degree of freedom (F) of a system related to number of component(C) and number of phase (P) following phase rule equation.

$$F = C - P + 2$$

Where F= number of degree of freedom
 C= number of components
 P= number of phases in an equilibrium system

Phase (P):

Phase is defined as, “any homogeneous physically distinct and mechanically separable portion of a system which is separated from the other part of the system by definite boundaries”.

A water system consisting of three phases: $\text{Ice}_{(s)} \rightleftharpoons \text{Water}_{(l)} \rightleftharpoons \text{Vapour}_{(g)}$

Component(C) :

Component is defined as, “the smallest number of independently variable constituents (Concentration), by means of which the composition of each phase can be expressed in the form of a chemical equation”.

A water system consisting of three phases: $\text{Ice}_{(s)} \rightleftharpoons \text{Water}_{(l)} \rightleftharpoons \text{Vapour}_{(g)}$

The composition of all the three phases is H₂O. Hence, the number of component is one.

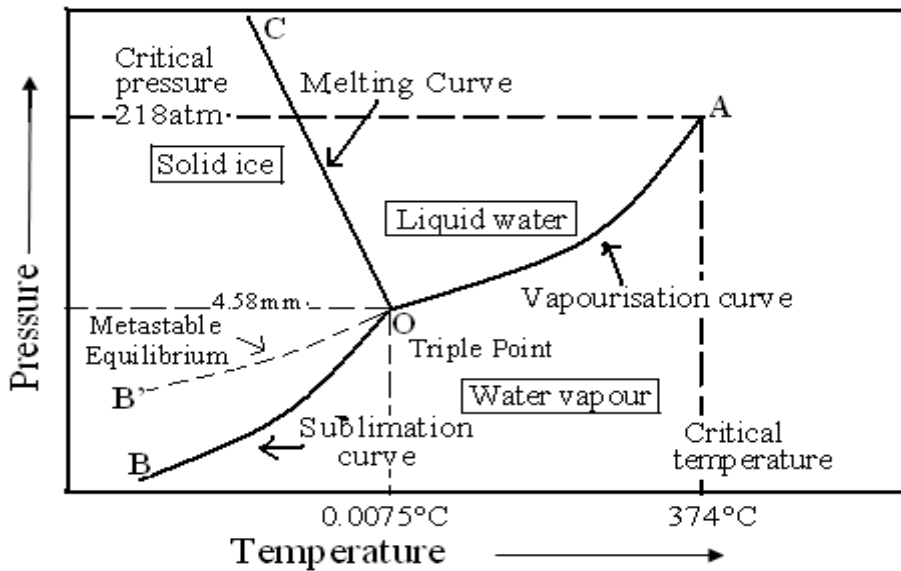
Degree of freedom (F):

Degree of freedom is defined as, “the minimum number of independent variable factors such as temperature, pressure and composition of the phases, which must be fixed in order to define the system completely.

$$F = C - P + 2$$

(A system having 1, 2, 3 or 0 degrees of freedom is called as univariant, bivariant, trivariant and non variant respectively).

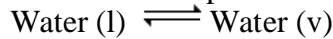
2. Draw and explain the phase diagram of one component system or water system or application of Phase rule to component system.



Phase diagram of water system contains curves, areas and Triple point.

1. Curve OA

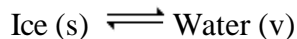
Curve OA is called Vapourisation curve. Along this curve liquid water and its vapour are in equilibrium



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

2. Curve OB

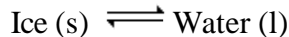
Curve OB is called sublimation curve of ice. Along this curve solid ice and its vapour are in equilibrium



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

3. Curve OC

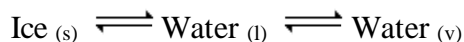
Curve OC is called melting point curve of ice. Along this curve solid ice and its water are in equilibrium



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

4. Point O (triple point)

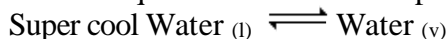
At point O three phases are in equilibrium (solid, liquid, vapour). This point is called triple point.



Therefore $F=C-P+2=1-3+2=0$. The point O is called non-variant point.

5. Curve OB' (metastable equilibrium)

Sometimes water can be cooled below 0°C without the formation of ice. this water is called super cooled water. The equilibrium between super cooled water & its vapour is called metastable equilibrium.



6. Areas:

Area AOC, BOC, AOB represents water (l), ice & vapour respectively. In each area only one phase will present. Therefore $F=C-P+2=1-1+2=2$.

Curves / Areas /Triple point	No. of phases in equilibrium	Degree of freedom
Curves OA,OB, OB', OC	2	1
Areas (AOB,BOC,AOC)	1	2
Triple point (O)	3	0

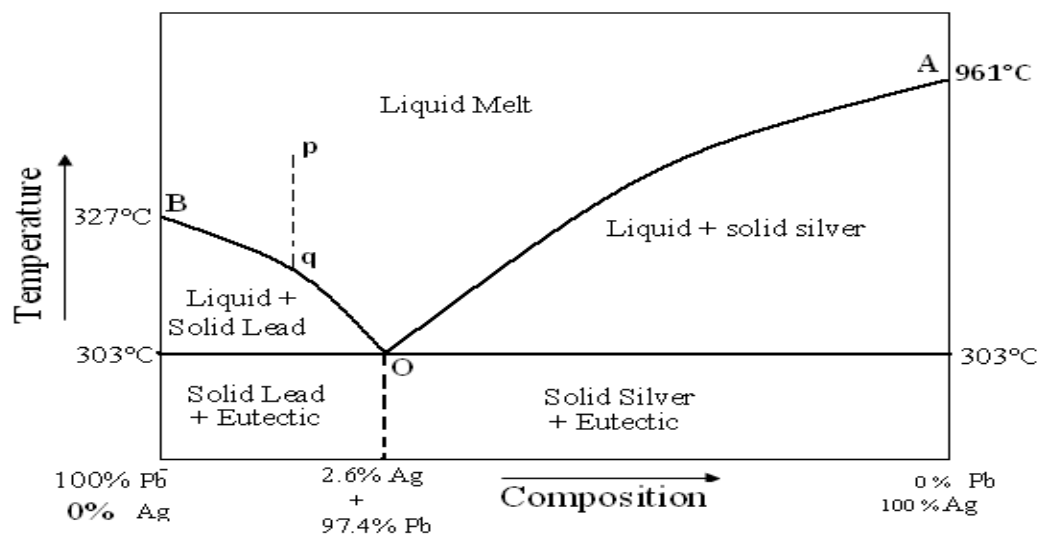
3. What is reduced phase rule? Explain lead-silver system or binary alloy system or simple eutectic system in detail and application of pattinson processes.

The system in which only the solid and liquid phases are considered and the gas phase is ignored is called a condensed system. Since the pressure is kept constant, the phase rule becomes

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

This equation is called reduced phase rule or condensed phase rule.

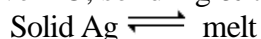
Lead-silver system:



The lead silver system contains curves, area & eutectic point.

1. Curve AO

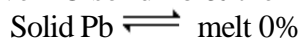
The curve AO is known as freezing point curve of silver. Point A is the melting point of pure silver (961°C). the curve AO shows the melting point depression of silver by the successive addition of Pb. Along this curve AO, solid Ag & the melt are in equilibrium.



Therefore $F' = C - P + 1 = 2 - 2 + 1 = 1$. It is univariant.

2. Curve BO

The curve BO is known as freezing point curve of Lead. Point B is the melting point of pure Lead (327°C). The curve BO shows the melting point depression of Lead by the successive addition of Ag. Along this curve BO solid Pb & the melt are in equilibrium.



Therefore $F' = C - P + 1 = 2 - 2 + 1 = 1$. It is univariant.

3. Point O (eutectic point)

The point O is called eutectic point. At point O, 3 phases (Solid Ag, Solid Pb & melt) are in equilibrium.



The temperature corresponding to eutectic point O is called eutectic temperature & the corresponding composition is called eutectic composition (2.6% Ag + 97.4% Pb).

4. Areas

The area above the line AOB has a single phase (melt)

Therefore $F' = C - P + 1 = 2 - 1 + 1 = 2$ The system is bivariant

The area below the line AO has TWO phases (solid Ag+Melt)

The area below the line BO has TWO phases (solid Pb+Melt)

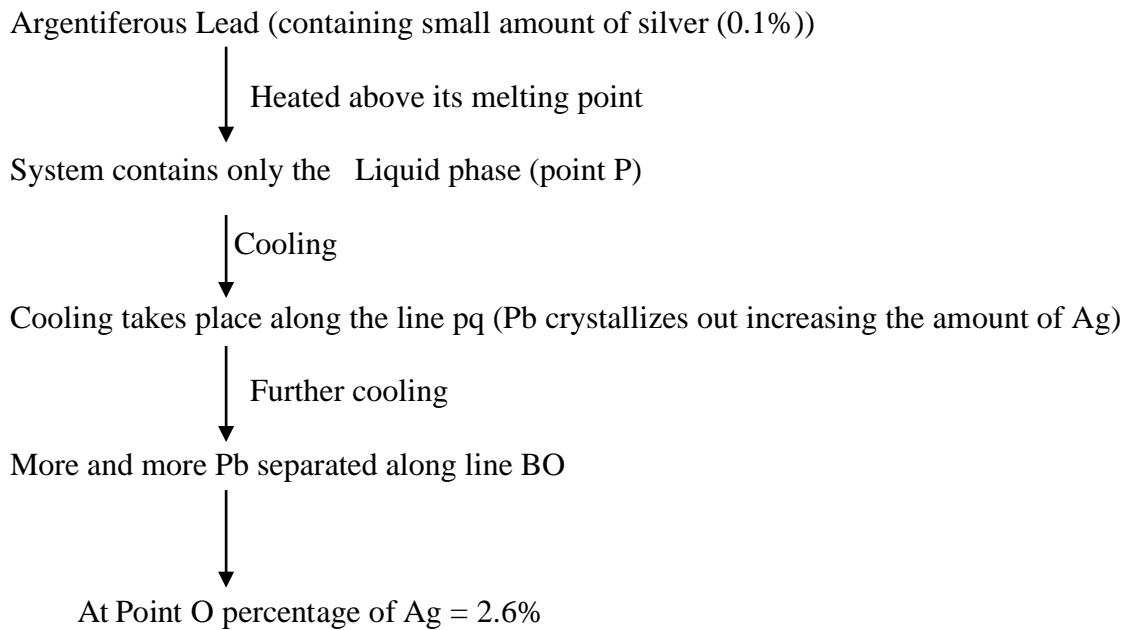
Therefore $F' = C - P + 1 = 2 - 2 + 1 = 1$ The system is univariant

Curves / Areas / Eutectic point	No. of phases in equilibrium	Degree of freedom
Curves AO, BO	2	1
Areas (AOB)	1	2
Below the line AO, Below the line BO	2	1
Eutectic point	3	0

APPLICATION OF PATTINSONS PROCESS

The Argentiferous lead, consisting of the very small amount of silver (0.1%) is heated to a temperature above its melting point to point p ,Only liquid phase will exist . It is then allowed to cool along the line pq as soon the point q is reached, lead is crystallized out and the solution will contain increasing amount of silver. And further cooling more and more lead is separated along the Line BO the solution will increase in silver until the point O is reached, where the percentage of silver raises to 2.6%

The process of increasing the proportion of silver in alloy is called Pattinsons process



4. Explain thermal analysis and cooling curves

Thermal analysis is the study of the cooling curves of various compositions of a system during solidification.

It is used for finding the shape of the freezing point curves for any system (involving metals) can be determined by thermal analysis. The form of the cooling curve indicates composition of the solid

Example-1 .Cooling curve for a pure solid

A pure substance in the fused state is allowed to cool slowly. During cooling the temperature is noted at different time intervals. Graph is plotted between temperature and time (Fig-1) Initially the rate of cooling is continuous. When it reaches the point b solid begins to appear. Now the temperature remains constant until the liquid melt is completely solidified .Solidification completes at the point c .The horizontal line bc represent the equilibrium between the solid and liquid melt. After the point c, temperature of the solid begins to decrease along the curve cd

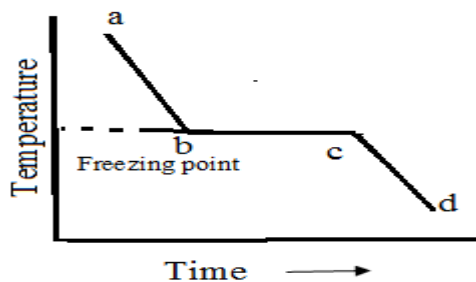


Figure-1 Cooling curve for a pure solid

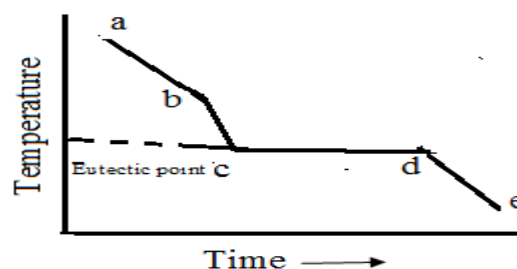


Figure-2 Cooling curve of a Mixture A+B

Figure-1 Cooling curve for a pure solid

Figure-2 Cooling curve of a Mixture A+B

(b). Example - 2 .Cooling curve of a Mixture A and B

If a mixture of two substances A & B in the fused states is allowed to cool slowly, the cooling curve is obtained is shown in Figure-2. Initially the rate of cooling is continuous. When it reaches the point b one substance (A or B) begins to solidify out of the melt, which is indicated by a break and the rate of cooling is different. On further cooling from the break point, c the second substance also begins to solidify. Now the temperature remains constant until the liquid melt is completely solidified. It forms the eutectic mixture (Line cd)

After the break point d cooling of solid begins. The temperature of the horizontal line cd gives the Eutectic temperature.

The experiment is repeated for different compositions of A & B. The various cooling curves are recorded. From the cooling curves of various compositions, the main phase diagram can be drawn by plotting composition in X-axis and Temperature in Y-axis (Figure-3)

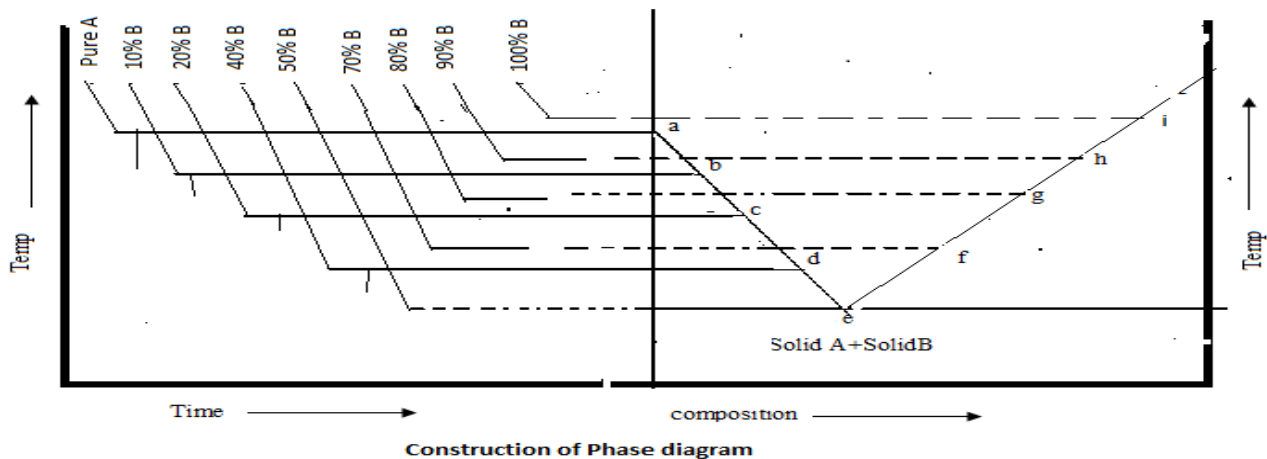


Figure-3. Cooling curve of various composition of two solid

Applications:

1. The melting point and eutectic temperature can be noted from the cooling curve
2. The percentage purity of the compounds can be found out from the cooling curve.
3. The behavior of the compound can be understood from the cooling curve.
4. The procedure of thermal analysis can be used to derive the phase diagram of any two component system.
5. Explain the types of heat treatment of alloys or steel. (8) (Refer Page No in book: 6.5- 6.9)

It is the process of heating and cooling of solid steel under controlled conditions

Purpose of heat treatment:

- (i) To improve magnetic and electrical properties
- (ii) To refine grain structure
- (iii) To remove imprisoned trapped gases
- (iv) To Remove internal stresses
- (v) To improve fatigue and corrosion resistance

Types of heat treatment of alloys:

The heat treatment processes are (1) Annealing (2) Quenching or hardening (3) Tempering (4) Normalizing (5) Carburizing and (6) Nitriding

(1) Annealing or softening

It is the process of heating the metal to high temperature and then cooled slowly in a furnace. It can be done two ways. They are (i) Low temperature annealing (ii) High temperature annealing

(i) **Low temperature annealing or Processes annealing:-** It is the process of heating steel to a temperature below the lower critical temperature followed by slow cooling.

Purpose:

- i) It improves machinability
- ii) It increases ductility reduces hardness.

(ii) High temperature annealing or Full annealing:- It is the process heating steel to a temperature about 30-50°C above the higher critical temperature. It is kept at the temperature for some time and then cooled to room temperature.

Annealing temperatures of various carbon steel

i. Mild steel=840-870°C

ii. Medium carbon steel=780-840 °C

iii. High carbon steel =760-780 °C

Purpose:

- i) To make the steel softer.
- ii) It increases ductility and machinability.

(2) Quenching or hardening

It is the process of heating the steel above the critical temperature and then suddenly cooled by immersing in oil or brine water. Hardening increases the hardness of the steel.

- i. The faster the rate of cooling harder will the steel produced.
- ii. Medium and high carbon steel can be hardened,
- iii. low carbon steel cannot be hardened

Purpose:

- (i) To increase the ability to cut other metals
- (ii) To increase the strength
- (iii) To increase the abrasion resistance

(3) Tempering:

Already hardened steel is heated to a temperature lower than its own hardening temperature. Then it is cooled slowly. In tempering the temperature to which hardened steel is reheated is great importance. Thus

- i) For retaining strength & hardness, reheating temperature should not exceed 400°C.
- ii) For developing better ductility & toughness, reheating temperature should be in the range 400-600°C

Purpose:

- i) To reduce the brittleness & harness.
- ii) To remove any stress & strain
- iii) To increase ductility & toughness

(4) Normalising:

It is the process of heating steel to a definite temperature or above its higher critical temperature & cooling gradually in air.

Purpose:

- i) To reduce the internal stress.
- ii) To increase the toughness.
- iii) It is suitable for engineering works.

(5).Carburising:

In this process steel is heated with charcoal in cast iron box to 950°C. It is allowed to remain as such for some times. Now the required amount of carbon is adsorbed. Then the article is cooled slowly within the iron box itself. The outer skin of the article is covered with high carbon steel containing about 0.8 -1.2% carbon.

Purpose:

- i) To make the steel harder.
- ii) To produce hard wearing surface.

(6).Nitriding:

It is the process of heating the metal alloy in the presence of ammonia at 550°C. the nitrogen obtained by the dissociation of ammonia, form hard nitride on the surface of the alloy.

Purpose:

To get super hard surface

6. What are ferrous alloys? Explain the composition, properties and uses of important ferrous alloys.

The alloys containing iron as one of the main components are known as ferrous alloys. The other elements present in ferrous alloys are Al, Ni, Cr, Co, Mn etc.

Example: a) Nichrome b) Stainless steel

a) Nichrome :

It is an alloy of nickel chromium and iron. Its composition is Ni (60%), Cr (12%) Fe (26%) Mn (2%)

Properties:

- It shows good resistance to oxidation and heat.
- It possess high melting point
- It possess High electrical resistance
- It can withstand heat upto 1100° C
- Steel containing 16-20% Cr with carbon 0.06-0.15% posses oxidation resistant up to 900° C
- Steel containing 18% Ni with small amount Cr posses heat resistant up to 900° C

Uses:

- It is used for making resistance coils, heating elements in stoves, Iron boxes.
- It is used in house hold electrical appliances
- It is used in making equipments which can withstand high temperature

b) Stainless steel or corrosion resistance steels:

Stainless steels resist corrosion by atmosphere and chemicals. The properties of corrosion resistance are due to presence of chromium and nickel. The protection against corrosion is due to the formation of dense, non porous film of chromium oxides on the surface of the metal. Stainless steels can be classified into two types

1. Heat treatable stainless steels

These contain 12-16% Cr and 1.2 %C.

Properties:

These are magnetic tough and can be worked in cold condition

Uses:

- They can be used upto 800°c
They are used in surgical instruments, Scissors etc.,
They are used in making blades and cutlery.

2. Non heat treatable stainless steels:

These steels posses less strength at high temperature. They are resistant to corrosion. These are classified into two types 1.Magnetic stainless steels 2. Non magnetic stainless steels

1. Magnetic stainless steels

It contains 12-22% Cr and 0.35%C.

Properties:

It can be rolled and machined using specially designed tools
It resists corrosion better than heat treatable stainless steels

Uses:

It is used in making chemical equipments
It is used for making automobile parts.

2. Non magnetic stainless steels

It contains 18-26% Cr 8-21% Ni and 0.15%C. total percentage of Cr and Ni in such steel is more than 23%

18/8 stainless steel

- 18/8 stainless steel contains 18% Cr and 8% Ni.
- It is the most widely used stainless steel

Properties:

It shows maximum resistance to corrosion
Corrosion resistance can be further increased by adding a small amount of molybdenum.

Uses:

It is used in making household utensils and sinks.
It is used in dental and surgical instruments.

UNIT –V FUELS AND COMBUSTION

1. What is fuel?

Fuel is a combustible substance which on burning gives large amount of heat. The main constituent of fuel is carbon

2. Write the characteristics of a good fuel.

- i) It should be cheap and readily available.
- ii) It should have higher calorific value
- iii) It should have low moisture content and volatile components
- iv) The products of combustion should not be harmful
- v) It should have low ash content

3. Define calorific value of fuel.

“The calorific value of fuel is defined as the total amount of heat evolved, when a unit mass of the fuel is completely burnt”.

4. Write briefly on the ranking of coal.

Coal is classified on the basis of its rank. The rank of coal indicates its degree of maturity.

Wood → Peat → Lignite → Bituminous → Anthracite

5. Distinguish between coal and coke. (or) How coke is superior to coal?

- The percentage of carbon content and the calorific value of coke is high.
- The percentage of carbon content and the calorific value of coal is lower than coke.
- The percentage of moisture, volatile and ash contents are higher in coal than coke.

6. What are caking and coking coal.

When coals are heated strongly, the mass becomes soft, plastic and fused to give a coherent masses are called Caking Coals. But if the mass so produced is hard, porous and strong then the coals are called Coking coals.

Coking coals possess lower volatile matter and are used for the manufacture of metallurgical coke.

(all coking coals are caking coals but all caking coals are not coking coals)

7. What are the characteristics of metallurgical coke? (AU 95)

- High Purity
- High Porosity
- High calorific value
- High mechanical Strength

8. What is carbonization indicate its different types? Or what is metallurgical coke? (Jan-08)

When coal is heated strongly in the absence of air (known as destructive distillation), it is converted into hard, strong, porous and coherent mass known as **metallurgical coke**. This process of conversion of coal to coke is called carbonization.

- Types: (i) Low temperature carbonization (LTC) 500-700 °C
(ii) High temperature carbonization (HTC) 900-1200 °C

9. Difference between Proximate and ultimate analysis

S.No	Proximate analysis	Ultimate analysis
1	It is determination of physical constituents like moisture ,volatile, ash and fixed carbon content in coal	It is determination of chemical constituents like carbon,hydrogen,and sulphur and oxygen content in coal
2	It gives the approximate composition of the main constituents of coal	It gives the exact composition of the elementary constituents of coal

10. What are the draw backs of presence of sulphur in the coal? (2014)

- i) Sulphur on burning forms SO₂ and SO₃, these products are harmful and corrodes the equipments
- ii) Coal containing sulphur is not suitable for the preparation of metallurgical coke These sulphur affects the properties of metal

11.What is cottrell’s process in crude oil refining

The crude oil from oil well is an extremely stable emulsion of oil and salt water, The crude is allowed to flow between two highly charged electrodes, when colloidal water droplets combine to form large drops, Which is then separated out from the oil.

12. What is knocking? How will you improve the anti knocking properties of petrol?

Knocking is a kind of explosion due to rapid pressure rise occurring in petrol engine (IC engine). Substances that reduces knocking property of the fuel are called anti-knocking agents.

Improvements of antiknock characteristics (or)

The octane number of fuel can be improved by

- Blending petrol of high octane number with petrol of low octane number,
- The addition of anti-knock agents like **Tetra-Ethyl Lead**
- Now a days **aromatic phosphate** are used as antiknock agents to avoid lead pollution.

13. Define octane number of a gasoline? How it can be improved?

Octane number is defined as ‘the percentage of iso-octane present in a mixture of iso-octane and n-heptane’ Iso-Octane-Octane number=100(knocking property =0) and N-heptane- Octane number=0(knocking property maximum).

Octane number can be improved by adding tetraethyl lead or aromatic phosphates to gasoline.

14. Define cetane number of diesel oil?

The cetane number is defined as ‘the percentage of hexa decane (cetane) present in a mixture of hexa decane and 2-methyl naphthalene, which has the same ignition lag as that of the fuel under test’

Ex: n-Cetane (hexa decane) cetane number =100 1-Methyl naphthalene (cetane number=0)

15. What is CNG? Give its constituents.(Dec-09)

When the natural gas is compressed it is called compressed natural gas (CNG)

CNG is derived from natural gas and the main constituent of CNG is methane.

CNG steel cylinder containing 15 kg of CNG at 1 atmospheric pressure.

16. What is LPG? Write its composition and uses

LPG is obtained as a by-product during fractional distillation of crude petroleum oil or cracking of heavy oil. It consists of propane and butane. It can be readily liquefied under pressure.

So it can be economically stored and transported in cylinders. Its calorific value is about 27,800 Kcal /m³

17. What is power alcohol? Mention the advantage.

When ethyl alcohol is blended with petrol at concentration of 5-10%, it is called power alcohol. It is used in internal combustion. The addition of ethyl alcohol to petrol increase its octane number, Ethyl alcohol blended with diesel it is called **E-Diesel**

- It is cheaper than petrol
- If any moisture is present ,power alcohol absorbs it
- As ethyl alcohol contains oxygen atoms, complete combustion occurs, so emission of CO, hydrocarbon, particulates is reduced.

18. Define Bio diesel.

Biodiesel is defined as mono alkyl esters of long chain fatty acids derived from vegetable oils Or fats. (Biodiesel can be blended with petroleum diesel and used)

Vegetable oil comprise of 90-95% triglycerides with small amount diglycerides, fatty acid, phospholipids

It is molecular weight 600-900

19. Differentiate gross and net calorific value of a fuel. (Jan-08)

S.No	Gross Calorific Value	Net Calorific Value
1	The amount of heat evolved, when a unit mass of the fuel is completely burnt and the products of combustion cooled to room temperature	The total amount of heat evolved, when a unit mass of the fuel is completely burnt and the products of combustion are allowed to escape
2	The latent heat of condensation of water vapour is included	The latent heat of condensation of water vapour is not included
	$= \frac{1}{100} \left[8080 \times \% C + 34500 \left(\% H - \frac{\% O}{8} \right) + 2240 \times \% S \right] \text{ kcal / kg}$	$\text{NCV} = \text{HCV} - \frac{9}{100} H \times 587 \text{ kcal/kg}$

20. What is ignition temperature and spontaneous ignition temperature?

Ignition:It is lowest temperature to which the fue must be heated, so that it starts burning smoothly
Coal=300⁰C

spontaneous ignition :The minimum temperature at which the fuel catches fire (ignites) spontaneous without external heating.

20. Mention the significance of flue gas analysis.

- Flue gas analysis gives an idea about the complete or incomplete combustion process.
- If the flue gases contain considerable amount of CO, it indicates that incomplete combustion
- If the flue gases contain considerable amount of O₂, it indicates that complete

21. Name the reagents used in flue gas analysis. Indicate their importance.

- Potassium hydroxide solution absorbs only CO₂
- Alkaline pyrogallic solution absorbs only O₂
- Ammonical cuprous chloride solution absorbs only CO

22. Define explosive range of a fuel.(AU 2014)

All gaseous fuels have two limits called upper limit and lower limit .These limits represent percentage by volume of fuel present in fuel-air mixture.

- Lower limit represents the smallest portion of combustible gas (fuel)
- Upper limit represents the largest portion of combustible gas.

The range covered by these two limits is called explosive range of a fuel.

PART-B

- Discuss briefly proximate analysis of coal and their significance. Page No.11.5-11.7
- Describe about ultimate analysis and its significance. (Dec-06) Page No: 11.7-11.13.
- Describe the Otto- Hofmann method of coke manufacture and the recovery of various by-products. (Or) Describe the manufacture of Metallurgical Coke.(Dec-08) Page No:11.16-11.19
- What is meant by crude petroleum? Discuss the principle steps in the refining of crude petroleum. Page No: 11.20-11.22
- Describe the different methods by which synthetic petrol can be obtained (Bergius process). (Dec-06) Page No: 11.23-11.25
- What is meant by Knocking in petrol engines? How is knocking prevented? Page NO: 11.25-11.26
- Explain the following (i) Compressed naturalgas (CNG) (ii) Liquid petroleum gas. (LPG) 11.30-11.33
- With a neat diagram describe the manufacture of water gas. Page No: 11.35-11.37.
- What is producer gas? How it is manufactured? (June-06) Page No: 11.33-11.35.
- Explain how the flue gas analysis is carried out by using Orsat's apparatus method with a neat diagram. (Apr-2000, Dec-06) Page No: 12.41-12.45.

1. Explain proximate analysis. Give its significance.

It involves the determination of % of moisture content, volatile matter, ash content & fixed carbon in coal.

(i) **Moisture content:** About 1 gram of air-dried coal sample is taken in a crucible. It is heated in a air-oven at 100-105°C for 1 hour. The lost in weight of the coal sample is found out. Then

$$\% \text{ of moisture in coal} = \frac{\text{loss in weight of the coal}}{\text{weight of Air- dried coal}} \times 100$$

(ii) **Volatile matter:** After the analysis of moisture content, the crucible with residual coal sample is Covered with lid. it is heated at 950°C for 7 minutes in a muffle furnace. The lost in weight of the coal sample is found out. Then

$$\% \text{ of Volatile mater in coal} = \frac{\text{loss in weight of the coal}}{\text{Weight of Air- dried coal}} \times 100$$

(i) **Ash content:**

After the analysis of volatile matter the crucible is heated without lid at 700°C for 30 minutes in a muffle furnace .The weight of ash content formed is found out. Then

$$\% \text{ of Ash content in coal} = \frac{\text{weight of ash formed/}}{\text{Weight of air dired coal}} \times 100$$

(iv) **Fixed carbon:** It is determined by the subtracting the sum total of moisture, volatile & ash content from 100.

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

Significance or importance of Proximate Analysis:

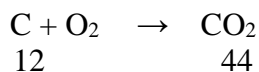
- (i) High % of moisture is undesirable because it reduces the calorific value of a coal, & increases the transport cost.
- (ii) High % of volatile matter is undesirable because it reduces the calorific value of a coal
- (iii) High % of ash content is undesirable because it reduces the calorific value of a coal. Increases the transport cost.
- (iv) High % of fixed carbon is desirable because it increases calorific value of coal.

2. Describe the ultimate analysis of coal. (2014)

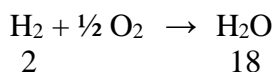
It involves the determination of % of 1. Carbon & Hydrogen, 2. Nitrogen 3. Sulphur 4. Ash content 5. Oxygen in coal.

1. Carbon & Hydrogen: A known amount of coal sample is burnt with O₂ in a combustion apparatus. The carbon & hydrogen present in the coal sample are converted into CO₂ & H₂O.

The liberated CO₂ is absorbed in known weight of KOH tube. The increase in weight of KOH gives the amount of CO₂ formed. H₂O vapor formed are absorbed known weight of anhydrous CaCl₂ tubes. The increase in weight of CaCl₂ tube gives the amount of H₂O formed



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



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

2. Nitrogen:

It is carried out by Kjeldahl's method. A known amount of coal is heated with Con. H₂SO₄ in presence of K₂SO₄ catalyst in a long necked flask called Kjeldahl's flask. Nitrogen in the coal is converted into ammonium sulphate and clear solution is formed. The clear solution is heated with excess NaOH. The liberated ammonia is absorbed in a known volume of 0.1N HCl. The volume of un used 0.1N HCl is calculated by titrating with 0.1N NaOH solution from this the volume of HCl acid consumed by ammonia is calculated.

$$\% \text{ of Nitrogen in coal} = \frac{1.4 \times \text{volume of HCl acid consumed} \times \text{Normality of HCl}}{\text{Weight of coal sample}}$$

3. Sulphur: A known amount of coal is completely burnt in a bomb calorimeter. Here sulphur is converted into sulphate. It is extracted with water. The extract is treated with BaCl₂ solution. BaSO₄ is precipitated. The weight of precipitate is found out.

$$\% \text{ of sulphur in coal} = \frac{32 \times \text{Weight of BaSO}_4 \text{ formed}}{233 \times \text{Weight of coal sample}} \times 100$$

4. Ash content:

After the analysis of volatile matter the crucible is heated without lid at 700°C for 30 minutes in a muffle furnace. The weight of ash content formed is found out. Then

$$\% \text{ of Ash content in coal} = \frac{\text{weight of ash formed}}{\text{Weight of air dried coal}} \times 100$$

4. Oxygen: The % of oxygen is calculated as follows,

$$\% \text{ of Oxygen in Coal} = 100 - \% \text{ of } (\text{C} + \text{H} + \text{N} + \text{S} + \text{Ash})$$

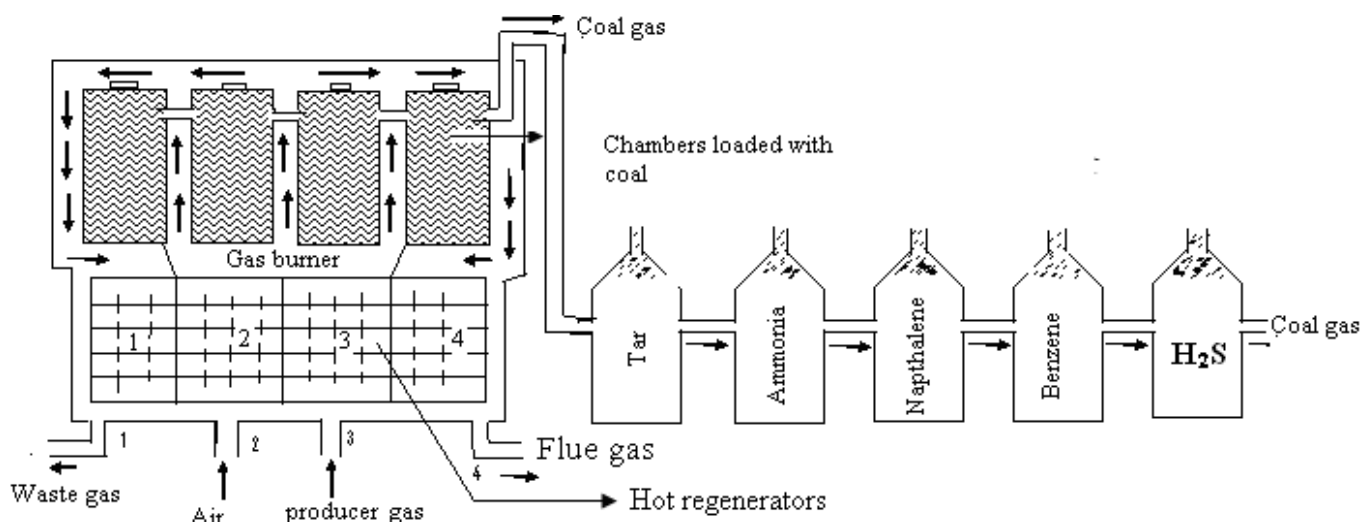
Importance or significance of Ultimate analysis:

1. Higher % of carbon & hydrogen increase the quality of coal and its calorific value.
2. Presence of Nitrogen in the coal is undesirable.
3. Presence of sulphur is undesirable. Because it is harmful and produces corrosion on equipments.
4. Lower % of Oxygen increases the calorific value of coal.

3. How Metallurgical coke is manufactured by Otto-Hoffman's method?

When bituminous coal is heated strongly in the absence of air, the volatile matter escapes out. The mass becomes hard, strong, porous coherent. It is called **metallurgical coke**.

Manufacture of Metallurgical coke by "Otto-Hoffman's by products" method:



This oven consists of a number of silica chambers. □ Each chamber provided with a charging coal at the top. The chamber is about 10-12 m long, 3-4 m height & 0.4 – 0.45m wide. □ Coal is introduced into the silica chambers and the chambers are closed. The chamber are heated 1200°C by burning the air & producer gas mixture.

The air and producer gases are preheated by sending them through 1 & 2 regenerators. Hot flue gases produced during burning passed through 1 & 4 regenerators until the temperature increased to 1000°C. For economical heating, direction of inlet gases and flue gases are changed frequently. (The above system of recycling the flue gases to produce heat energy is called the regenerating system of heat economy.) When the process is complete, the coke is removed and quenched with water.

Time taken for complete carbonization is about 12-20 hours. The yield of coke is 70%. From out coming flue gas, valuable products like Tar, ammonia, benzene. and H₂S are obtained..

Recovery of by products:

- (i) **Tar:** the flue gases are first passed through a tower, in which liq. NH₃ is sprayed. Tar is collected at the bottom of the tank.
- (ii) **Ammonia:** The gases are then passed through 2 nd tower, in which water is sprayed. NH₃ gets converted to NH₄OH.
- (iii) **Naphthalene:** The gases are again passed through next tower, in which cooled water is sprayed. Naphthalene gets condensed..
- (iv) **Benzene:** The gases are passed through next tower, where petroleum oil is sprayed, benzene gets condensed.
- (v) **H₂S gas:** The remaining gases are then passed through a purifier, where H₂S gas is retained(removed). The final gas left out is called coal gas.

Advantages:

- (i) Valuable by product like NH₃, benzene, etc are obtained.
- (ii) The carbonization time is less. (iii) Heating is done by externally by producer gas.

4. What is meant by crude petroleum? Discuss the principle steps in the refining of crude petroleum.

The process of removing impurities and separating the crude oil into various fractions (having different boiling points) is called refining of petroleum or crude oil.

Step-I Separation of Water

The crude oil is allowed to flow between highly charged electrodes. Here colloidal water droplets combine to form large water drops, which can be removed from the oil.

Step-II Removal of Harmful Sulphur Compounds

The crude oil is treated with copper oxide to remove sulphur. The copper Sulphide formed is separated out by filtration.

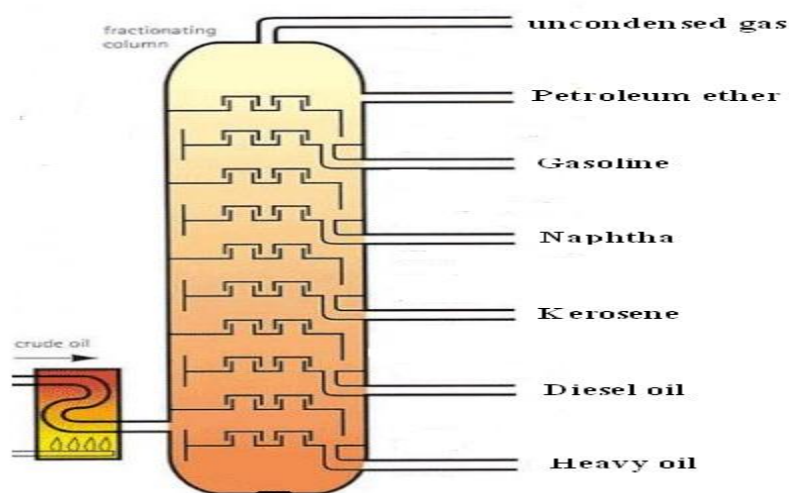
Step-III Fractional Distillation

The purified crude oil is then heated to about 400°C in an iron retort. The crude oil is vapourised.

The vapours are then passed into the bottom of the fractionating column. The fractionating column is a tall cylinder containing a number of horizontal stainless steel trays at short distances. Each tray is provided with a small chimney covered with a loose cap.

The fractions having higher boiling points condense at lower trays. The fractions having lower boiling points condense at higher trays.

The various fraction obtained are given in the table.



Petroleum ether Gasoline Naphtha Kerosene Diesel oil Heavy oil

S.No	Name of the Fraction	Boiling Range	Uses
1	Uncondensed gases	Below 30°C	As a fuel under the name of LPG
2	Petroleum ether	30-70°C	As a solvent
3	Gasoline or Petrol	40-120° C	Fuel for internal combustion of engines.
4	Naphtha	120-180° C	As a solvent in paints and in dry cleaning
5	Kerosene oil	180-250° C	Fuel for stoves and jet engines.
6	Diesel oil	250-320° C	Diesel engine fuel
7	Heavy oil	320-400° C	Fuel for ship and production of gasoline by cracking

Heavy Oil on fractionation gives:

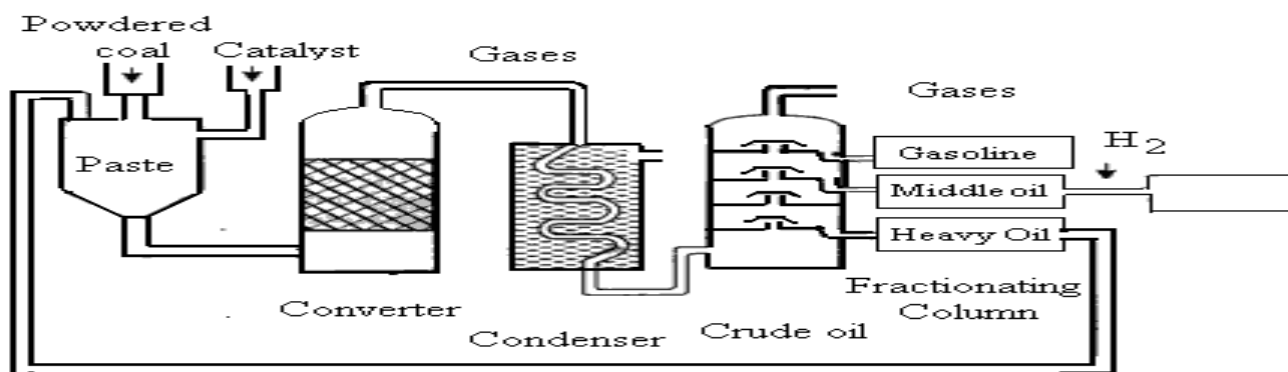
- (i) Lubricating Oil – used as lubricants
- (ii) Petroleum jelly (or) Vaseline-used in medicine and cosmetics
- (iii) Greases-used as lubricant
- (iv) Paraffin Wax-used in boot polishes in making handles etc
- (v) Pitch at about 400°C –used for making roads, for making water proof roofing etc

5. What do you mean by hydrogenation of coal? How Synthetic petrol is manufactured by Bergius Process? (Or)How solid fuel is converted into liquid fuel? Explain in detail.

If coal is heated with hydrogen at high temperature and under high pressure, it is converted to petrol. The preparation of liquid fuel from solid coal is called hydrogenation of coal (or) synthetic petrol.

The finely powder coal is made into a paste with heavy oil along with a catalyst (Ni or Sn oleate) The paste is passed along with H_2 gas into the converter. Here the paste is heated to $400\text{-}500^{\circ}\text{C}$ under a pressure of 200-250 atm.

During this process H_2 combine with coal to form saturated higher hydrocarbons. These undergo further decomposition at high temperature to give a mixture of lower hydrocarbons. The mixture is passed to a condenser where crude oil is obtained.



The crude oil is then fractionated to (i) Gasoline (ii) Middle Oil (iii) Heavy Oil.

The middle oil is further hydrogenated in vapor phase to give more gasoline. The heavy oil is recycled for making paste with fresh coal dust. The yield of gasoline about 60% of the coal used.

6. What is meant by Knocking in petrol engines? How is knocking prevented?

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

Causes of knocking in petrol engine:

In petrol engine, a mixture of gasoline vapour and air in the ratio 1:17 is compressed and ignited (by an electric spark). If the combustion proceeds in a regular way there is no problem of knocking . But in some cases the rate of combustion will not be uniform due to unwanted chemical in gasoline .The rate of ignition of the fuel gradually increases and the final portion of fuel air mixture gets ignited instantaneously producing an explosive sound known as knocking. Knocking property of the fuel reduces the efficiency of the engine.

Improvement of Antiknocking properties (or) prevention of knocking:

1. Blending (mixing) petrol of high octane number with petrol of low octane number. (the octane number of the later can be improved).
2. Addition of antiknock agent like TEL (Tetra ethyl lead) .
3. Now a days **aromatic phosphate** are used as antiknock agents to avoid lead pollution.

7. Explain the following (i) Compressed naturalgas (CNG) (ii) Liquid petroleum gas. (LPG)

(i) Compressed Natural Gas: (CNG)

- (i) Natural gas (CH_4) compressed to a pressure of about 1000 atm is known as CNG.
- (ii) Its calorific value is 12000-14000kcal/m³
- (iii)It is fully of methane only & derived from natural gas.

(iv) Its composition is as follows. Methane = 88.5% Ethane = 5.5 % Propane = 3.5% Butane=1.8% Pentane=0.5%

Uses: CNG is a cheapest, clearest & the least polluting fuel for automobiles instead of petrol or diesel.

(ii) Liquid Petroleum Gas: (LPG)

(i) It is obtained as a by-product during the Fractional distillation of crude oil and cracking of heavy oil.

(ii) Its composition is n- Butane= 38.5%, Isobutene =37%, Propane =24.5%

(iii) Its calorific value is 25,000 kcal /m³

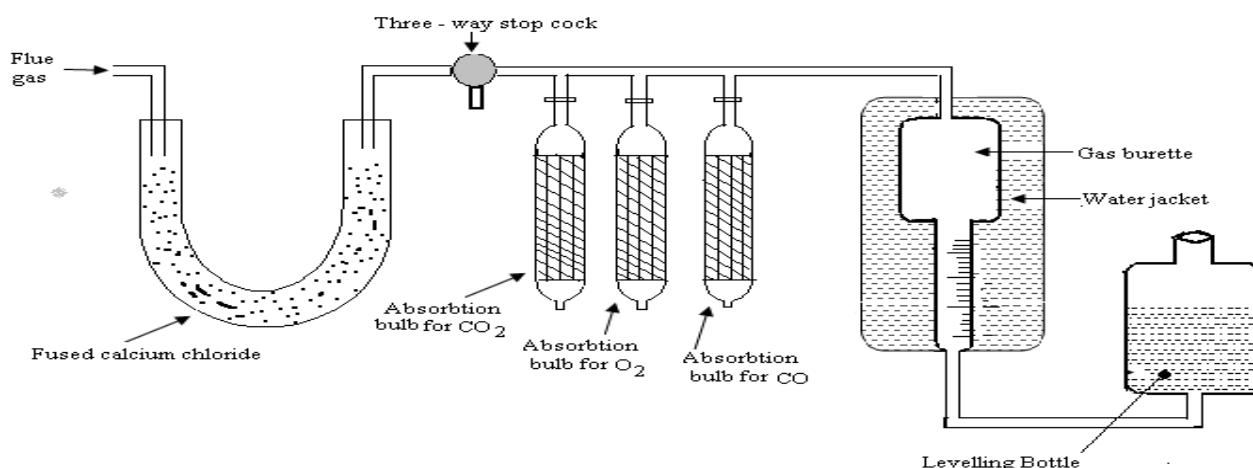
(LPG is marketed under the trade names like Indane, HP, and Bharat gas in steel cylinders under high pressure. A small amount of Ethyl mercaptan is added during filling of cylinders to help in detecting leakage of gas. LPG ensures complete combustion with no smoke & causes the least environmental pollution.)

Uses:

1. It is used as a domestic fuel.
2. It is used as a fuel in vehicles (i.e) motor fuel.
3. It is used in industries & laboratories

10. Describe flue gas analysis by Orsat's (apparatus) method.

Flue gas analysis is carried out by Orsat apparatus method. A mixture of gases like CO₂, CO, O₂ & N₂ etc coming out from the combustion chamber is called flue gases. If the flue gas contains, CO -- It indicates incomplete combustion & O₂ -- It indicates excess supply of air used in combustion



Apparatus:

It consists of a horizontal tube. At one end of this tube, U tube containing fused CaCl₂ is connected through 3 way stop cock. The other end of this tube is connected with a graduated burette. The lower end of the burette is connected to a Water reservoir through rubber tube. The level of water in the burette can be increased or decreased by raising or lowering the water reservoir. The horizontal tube is also connected with 3 different absorption bulbs 1, 2, 3 for absorbing CO₂, O₂. and CO .

Bulb: 1 It contains KOH solution .It absorbs CO₂ only.

Bulb: 2 It contains alkaline pyrogallol solution. It absorbs CO₂, & O₂

Bulb: 3 It contains Ammoniacal cuprous chloride solution .It absorbs CO₂, CO and O₂

The 3 way stop cock is opened to the atmosphere and the reservoir is raised to fill the burette completely with water. The 3 way stop cock is now connected to the flue gas supply. The flue gas is passed in to the burette till the volume of flue gas is 100ml in the burette. (By adjusting Water reservoir). Then the 3 way stop cock is closed

Absorption of CO₂

The bulb-I stopper is opened .all the flue gas in the burette is passed into the bulb-1 by adjusting the water reservoir. The flue gas enters into the KOH solution .CO₂ present in flue gas is absorbed by KOH solution. The gas is send back to the burette. The decrease in volume of flue gas indicates the volume of CO₂ present in 100ml of flue gas.

Absorption of O₂

The stop cock of bulb is closed .The bulb-2 stopper is opened .all the flue gas in the burette is passed into the bulb-II by adjusting the water reservoir. The flue gas enters into the Alkaline pyrogallol solution .O₂

present in flue gas is absorbed by Alkaline pyrogallol solution. The gas is send back to the burette. The decrease in volume of flue gas indicates the volume of O₂ present in 100ml of flue gas.

Absorption of CO

Now the stop cock of bulb 2 and is closed .The bulb-3 stopper is opened .all the flue gas in the burette is passed into the bulb-III by adjusting the water reservoir. The flue gas enters into the Ammonical cuprous chloride solution .CO present in flue gas is absorbed by Ammonical cuprous chloride solution. The gas is send back to the burette. The decrease in volume of flue gas now indicates the volume of CO present in 100ml of flue gas.

Significance:i). It gives a clear idea about the complete or incomplete combustion process

ii).If the flue gas contains considerable amount of CO, it indicates incomplete combustion and short supply of O₂

iii). If the flue gas contains considerable amount of O₂ , it indicates complete combustion

Precautions

i).All the flue gas in the burette should be passed into each of the absorbing solution (bulb-1, 2,3etc).

ii).CO₂, O₂, CO should be absorbed in specified order only.

i).The measurement of CO in flue gas should be done carefully

11. Explain the gross and net calorific values and how are they related? (Jan-06)

The gross calorific value of fuel is defined as “the total amount of heat evolved, when a unit mass of the fuel is completely burnt and the products of combustion are cooled to room temperature .

Gross calorific value of fuel is calculated by **Delong’s formula**

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

Where C, H, O and S represent the % of the elements present in the fuel respectively.

Where 8080=calorific value of carbon

34500= calorific value of Hydrogen

2240= calorific value of Sulphur

(The Carbon, hydrogen and sulphur in the fuel combine with oxygen with air to form carbon dioxide, water vapour and sulphur dioxide, releasing 8080 kcals, 34500 kcals & 2240 kcals of heat respectively.

However all the oxygen in the fuel is assumed to be present in combination with hydrogen in the ratio H: O as 1: 8 by weight. So the surpluss hydrogen available for combustion is H-O/8)

Net Calorific Value (NCV) or Lower Calorific Value (LCV)

The net calorific value of fuel is defined as “the net amount of heat evolved, when a unit mass of the fuel is completely burnt and the products of combustion are allowed to escape

NCV = GCV – Latent heat of condensation of water vapour produced

= GCV – Mass of hydrogen x 9 x Latent heat of condensation of Water vapour produced

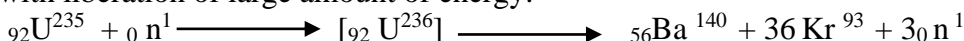
$$\text{NCV} = \text{HCV} - \frac{9}{100} \text{H} \times 587 \text{ kcal/kg}$$

UNIT – III ENERGY SOURCES

SECTION – A

1. Define nuclear fission.

Nuclear fission is defined as “the process of splitting of heavier nucleus into two (or) more smaller nuclei with liberation of large amount of energy.



2. What is nuclear fusion? Give an example.

It is the process of combination of lighter nuclei into heavier nuclei, with liberation of large amount of energy. Eg. Nuclear fusion occurs in sun



3. Differences between nuclear fission and nuclear fusion reactions

S.no	Nuclear fission	Nuclear fusion
1.	It is the process of splitting of heavier nucleus into two (or) more smaller nuclei	It is the process of combination of lighter nuclei into heavier nuclei
2	It emits radioactive rays	It does not emit radioactive rays
3.	It occurs at ordinary temperature	It occurs at high temperature(> 10 ⁶ K)
	${}_{92}\text{U}^{235} + {}_0\text{n}^1 \longrightarrow [{}_{92}\text{U}^{236}] \longrightarrow {}_{56}\text{Ba}^{140} + {}_{36}\text{Kr}^{93} + 3{}_0\text{n}^1$	${}_1\text{H}^2 + {}_1\text{H}^2 \longrightarrow {}_2\text{He}^4 + \text{Energy}$

4. What is neutron multiplication factor?

The number of neutrons resulting from a single fission is known as the multiplication factor.

5. What is nuclear chain reaction?

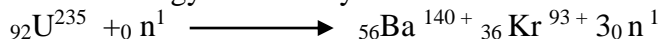
A fission reaction, in which the neutrons from the previous step continue to propagate and repeat the reaction is called nuclear chain reaction.

6. What is super critical mass and sub-critical mass of U²³⁵?

- If the mass of the fissionable material is more than the critical mass, it is called super critical mass.
- If the mass of the fissionable materials is smaller than the critical mass, it is called Sub-critical mass.

7. What is nuclear energy?

The energy released by the nuclear fission is called nuclear fission energy (or) nuclear energy.



8. What are the drawbacks of nuclear energy?

- The nuclear radiation can damage the structure of cells in the human body.
- Disposal of nuclear waste is the biggest problem.
- It causes sterility in young generation.
- It causes diseases like cancer and blindness.
- It causes serious pollution problems.

9. What are thermo nuclear reactions? Give one example.

High temperature is needed for nuclear fusion reaction. It is called thermo nuclear reactions. Such a high temperature is generated by a nuclear fission reaction.

Ex: In Hydrogen bomb, fusion occurs by the fission of atom bomb, (which acts as a trigger).

10. Mention the factors that hinder the nuclear chain reaction.

The factors that hinder the nuclear chain reactions are

- Some of the neutrons may escape from the surface to the surroundings.
- Some of the neutrons may be absorbed by U²³⁸ present as impurity.

11. What is a nuclear reactor?

The arrangement of equipment used to carry out fission reaction under controlled conditions is called a nuclear reactor.

12. What is light water nuclear – power plant?

Light water nuclear power plant is the one, in which U²³⁵ fuel rods are submerged in water. Here the water acts as coolant and moderators.

13. What are moderators? Give some examples.

The substances used to slow down the neutrons are called moderators.

Ex: Ordinary water, Heavy water, Graphite, Beryllium etc.

14. What is Breeder reactor?

Breeder reactor is the one which converts non- fissionable material (such as U²³⁸ & Th²³²) into fissionable material(such as U²³⁵ & Pu²³⁹).

15. What is fissile and fertile nucleides?

- The fissionable nucleides such as U²³⁵ & Pu²³⁹ are called fissile nucleides.
- The non fissionable nucleides such as U²³⁸ & Th²³² are called fertile nucleides.

16. Mention any two differences of a nuclear reaction and chemical reaction.

S.No	Nuclear reaction	Chemical reaction
1	Rapid exothermic reaction	Slow reaction
2	Initiated by neutrons	Initiated by heat or cold

17. What is meant by solar energy conversion? How is it done?

Solar energy conversion is the process of conversion of direct sunlight into more useful forms (heat energy, electrical energy). This solar energy conversion occurs by the following two mechanisms.

- Thermal conversion
- Photo conversion

18. What is photo galvanic cell or solar cell? (AU-08/09)

Photo galvanic cell is the one, which converts the solar energy directly into electrical energy. It consists of a p type semi conductor and n type semi conductor. They are in close contact with each other.

19. Explain the applications of solar cells.

1. Solar cells are used in calculators, electronic watches, radios and TVs.
2. Solar cells are superior to other type of cells, because these are non-polluting and eco-friendly.
3. Solar energy can be stored in Ni-Cd batteries and lead acid batteries.
4. Solar cells can be used to drive vehicles.
5. Solar cells, made of silicon are used as a source of electricity in space craft and satellites.

20. What is Wind energy? How is it obtained?

Moving air is called wind. Energy recovered from the force of the wind is called wind energy. The wind energy is harnessed by making use of wind mills.

21. What are the drawbacks of wind energy?

1. The wind forms produce noise pollution.
2. Birds are killed sometimes when they hit on Wind farms.

PART -B

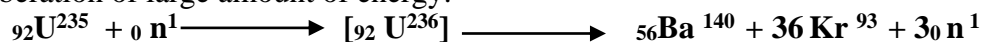
1. State any four characteristics of nuclear fission reaction. (AU – 09)
2. What are nuclear chain reactions? Explain how the amount of nuclear energy can be improved. (AU – 13)
3. Give an account of light water nuclear power plant with a neat diagram. (AU – 05, 09&10)
4. Describe the breeder reactor. (AU – 10)
5. State the principle and applications of solar batteries. (AU – 08&13)
6. Write a note on wind energy. (AU – 09)

1. Differences between fission and fusion reaction

S.No	Nuclear fission	Nuclear fusion
1	It is a process of breaking of a heavier nucleus	It is a process of combination of lighter nuclei.
2	It emits radioactive rays	It does not emit any kind of radioactive rays
3	The mass number and atomic number of new elements are lower than that of starting elements	The mass number and atomic number of product is higher than that of starting elements
4	It occurs at ordinary temperature	It occurs at high Temperature
5	It gives rise to chain reaction	It does not give rise to chain reaction
6	It emits neutrons	It emits positrons
7	It can be controlled	It cannot be controlled

2. Explain nuclear fission and nuclear fusion reactions with suitable examples.**Nuclear fusion:**

Nuclear fission is defined as “the process of splitting of heavier nucleus into two (or) more smaller nuclei with liberation of large amount of energy.

**Characteristics of Nuclear fission:**

- (i) It is a process of breaking of a heavier nucleus
- (ii) It emits radioactive rays
- (iii) It occurs at ordinary temperature
- (iv) It gives rise to chain reaction
- (v) It can be controlled

Nuclear fusion:

It is the process of combination of lighter nuclei into heavier nuclei, with liberation of large amount of energy.

Eg. Nuclear fusion occurs in sun



Nuclear fusion reaction requires very high temperature (100 million °C). Hence it occurs in sun.

Characteristics of Nuclear fusion:

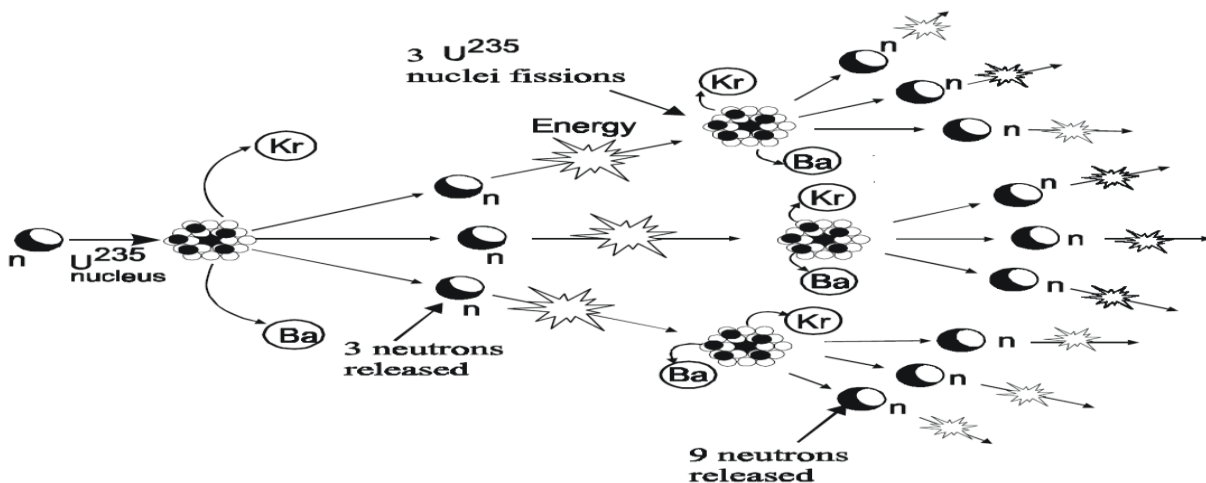
- (i) It is a process of combination of lighter nuclei
- (ii) It does not emit any kind of radioactive rays
- (iii) It occurs at high Temperature
- (iv) It does not give rise to chain reaction
- (v) It cannot be controlled

3. What are nuclear chain reactions? Explain how the amount of nuclear energy can be improved.

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

Criteria for nuclear chain reaction or Improvement of nuclear energy:

- (i) For a nuclear chain reaction to continue sufficient amount of U^{235} must be present
- (ii) The mass greater (super critical mass) or lesser (sub critical mass) than the critical mass of U^{235} (1kg to 100kg) will hinder the propagation of chain reaction



2. Describe using a block diagram the light water nuclear reactor for power generator with neat diagram

The equipment used to carry out fission reaction under controlled conditions is called a **nuclear reactor**.

Components of a nuclear reactor:

1) Fuel Rods: The fissionable material, (enriched) U^{235} is used as fuel rods in nuclear reactor.

Functions: It produces heat energy and neutrons which starts the nuclear reaction.

Ex: Uranium (U^{235}) and Pu^{239}

2) Control Rods: Cadmium or Boron rods are suspended between the fuel rods. By moving these control rods fission reactions can be controlled. (By absorbing the excess neutrons)

Ex: Boron and Cadmium rods.

3) Moderators: The substance is used to slowdown the neutrons are called neutrons

Functions: The kinetic energy of fast moving neutrons reduced to slow moving neutron **Ex:** Ordinary water, Heavy water, Graphite and Be.

4) Coolants: To absorb the heat produced in the reactor, a coolant (liquid) is circulated in the reactor Ex: Ordinary water, Heavy water, liquid metals and gases.

Functions: It cools the fuel core.

5) Pressure vessel: It encloses the core. It also provides the entrance and exit passages for coolant.

Functions: It withstands the high pressure (Pressure 200 kg/cm²)

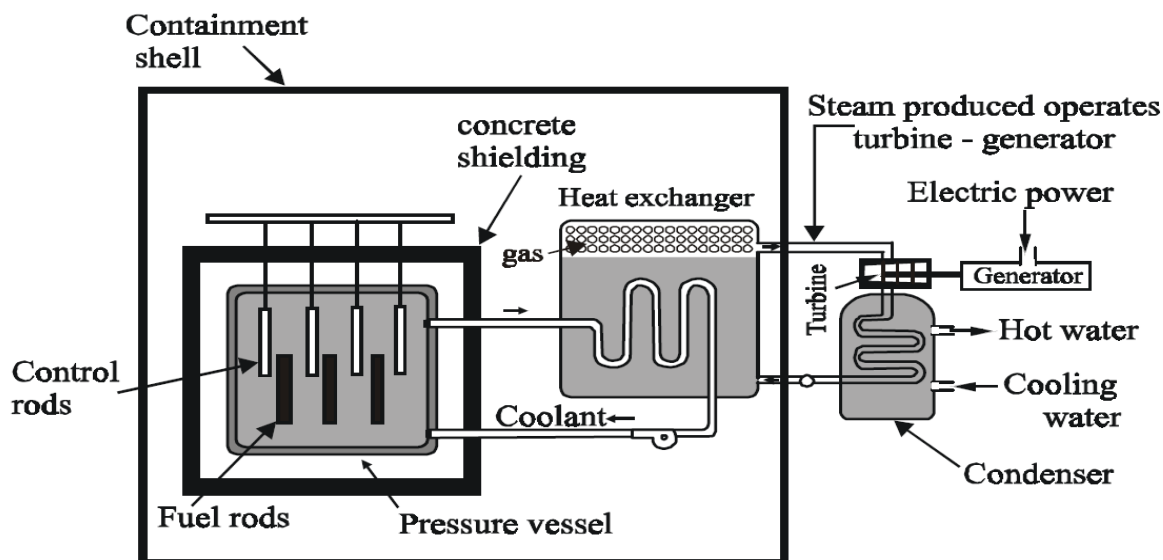
6) Shielding: The nuclear reactor is enclosed in a thick concrete shield (more than 10 metres thick) The environment and operating personnel are protected in case of leakage of radiations.

7) Turbine: The steam generated in the heat exchanger is used to operate a steam turbine. It drives (operates) a generator to produce electricity

3. Explain the power generation from light water nuclear reactor or Explain the method of conversion of nuclear energy into electrical energy in a nuclear reactor (AU-Jun2014)

Working:

- (i) Light water nuclear power plant is one in which U²³⁵ fuel rods are submerged in water.
- (ii) Here the water acts as coolant and moderator.
- (iii) The fission reaction is controlled by inserting or removing the control rods of B¹⁰ from the spaces in between the fuel rods.
- (iv) The heat emitted by U²³⁵ in the fuel core is absorbed by the coolant.
- (v) Heat coolant (Water at 300°C) then goes to the heat exchanger containing sea water.
- (vi) The coolant transfers heat to sea water which is converted into steam.
- (vii) The steam then drives (operates) the turbines, generating electricity.

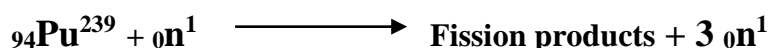
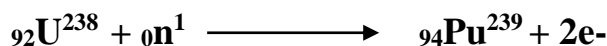


Drawbacks of Nuclear power plant:

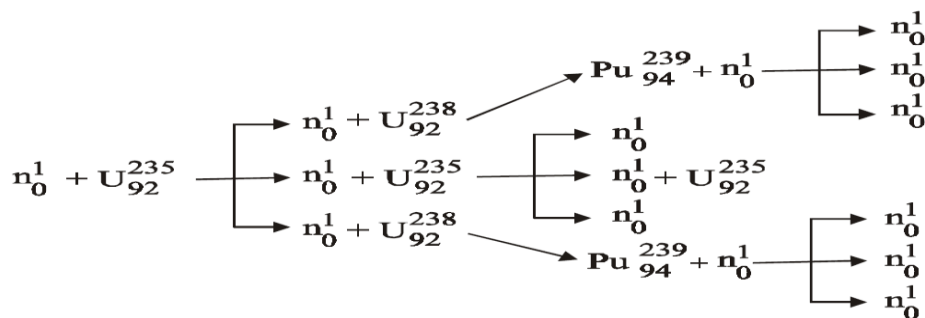
- (ii) Nuclear power plant cause a serious pollution to environment
- (iii) Disposal of nuclear waste is a problem. It is packed in concrete barrels which are buried deep in the sea

3. Describe the breeder reactor or Write a detailed note on Breeder reactor.

Breeder reactor is the one which converts **non- fissionable material (U²³⁸, Th²³²)** into **fissionable material (U²³⁵, Pu²³⁹)**. Thus the reactor produces (breeds) more fissionable material than it consumes.



Working:



- In breeder reactor, the three neutrons emitted in the fission of U^{235} .
- One neutron is used to propagate fission chain.
- The other two neutrons are react with U^{238} thus two fissionable ${}_{94}\text{Pu}^{239}$ are produced for each atom of U^{235} consumes,
- Thus the breeder reactor produces more fissionable material than it consumed. Hence the reactor is called breeder reactor. (Hence Pu^{239} is a man-made nuclear fuel or secondary nuclear fuel)

Significance:

- Non fissionable nucleides such as U^{238} and Th^{232} (Fertile nuclides) are converted into fissionable material such as U^{235} , Pu^{239} (fissile nuclides)
- Breeder reactor efficiency is more due to regeneration of fissile nucleides

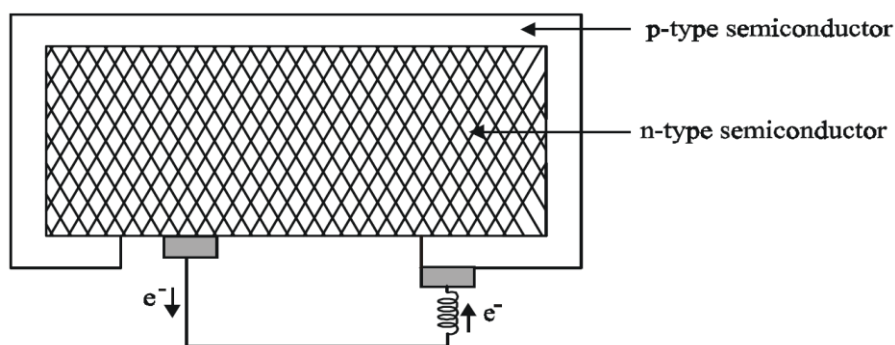
4. What is photovoltaic cell? Explain the construction and working of photovoltaic cell with a diagram Photo galvanic cell or Solar cell

It is a device used for converting solar energy into electricity directly . It is made by interconnecting a large number of photovoltaic cells

Principle:

The principle of Solar cell is based on photovoltaic effect. When light radiation falls on a two layer of p-n semi conductors, A potential difference between two layers produced. This potential difference causes flow of electrons and produces electricity

Construction and Working:



Solar cells consist of P-Type semiconductor (such silicon doped with Boron) and n-Type semiconductor (such us Silicon doped with Phosphorous) they are closed in closed contact with each other

When sun rays all on the top layer of p- type semiconductor, electrons from valence band are promoted to conductance band and cross the p-n junction into the n-type semiconductor. A potential difference is set up between the two layers. This causes flow of electrons and produces electricity. When the „p“ and „n“ layers are connected to an external circuit, electrons flow from „n“ layer to „p“ layer and current is generated.

Application of Solar Cell

1. Lighting purpose

Nowadays electrical street lights are replaced by solar street lights.

2. Solar pumps are run by solar battery

Solar battery produces more electricity to run water pump, street lights etc.

They are also used in remote areas where conventional electricity is not available.

3. Solar cells are used in calculators, electronic watches, radio and TV etc.

4. Solar cells are superior to other type of cells, because they are non-polluting and ecofriendly.

5. Solar cells are used to drive vehicles.

6. Silicon solar cells are used as a source of electricity in space crafts and satellites.

Advantages of Solar cells

1. Solar cells are used in remote areas, forests and hilly regions.

2. Maintenance cost is minimum.

3. Solar cells are pollution free.

4. They have long life.

Disadvantages

1. Solar cells are costly.

2. Storage of solar energy is not possible with.

5. Write a note on wind energy or how is wind energy harnessed? What are its advantages and limitation?

Moving air is called wind. Energy recovered from the forces of wind is called wind energy.

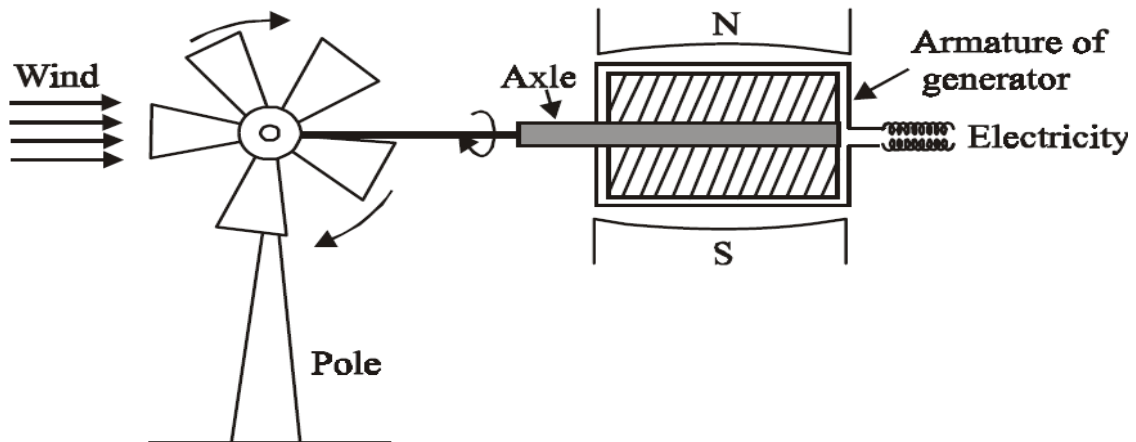
Methods of harnessing wind energy

Wind mill: It is a device used to convert wind energy into mechanical energy and then electrical energy

Sequence of energy conversion



Construction and Working of wind mill



It consists of a wheel containing number of blades .The wheel rotates about an axle mounted on a pole. The wind energy rotate the wheel .One end of the axle is connected to the armature of a generator .It rotates between two poles of a strong magnet. Another end of the axle is connected to the shaft of the wind mill. When wind falls on the wheel a wind mill, it rotates and produces electricity.

Wind Farms:

A large number of wind mills are connected together to produce electricity on a large scale is called wind farm..

Advantages of wind energy

(i)It is very cheap and economical.

(ii)It is renewable.

(iii)It does not cause pollution.

Disadvantages

(i) They produce noise.

(ii) Some birds are killed due to collision on wind mills or wind farms

(iii)Wind turbines interfere with electromagnetic signals (TV, Radio signals).

USES OF WIND ENERGY:

1. It is used to produce electricity

2. It is used to operate water pumps.
3. It is used to move the sail boats in lakes ,rivers and seas.

BATTERIES

1. What is a battery? How does it differ from a cell? (AU-09)

A Battery is an arrangement of several electrochemical cells connected in series. It can be used as a source of direct electric current. Thus, Cell contains only one anode and cathode. Battery contains several anodes and cathodes.

2. What are the important requirements of a battery?

1. It should be light and compact for easy transport.
2. It should have long life both when it is being used and when it is not used.
3. The voltage of the battery should not vary appreciably during its use.

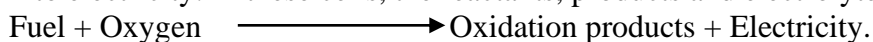
3. What is a primary battery? Give an example. (AU-Jan-10)

In primary cells, the electrode reactions cannot be reversed by passing an external electrical energy. The reactions occur only once and after use they become dead. Therefore, they are not chargeable.

Ex: Alkaline battery

4. What are fuel cells? (AU-08/09)

Fuel cell is a voltaic cell, which converts the chemical energy of the fuels directly into electricity without combustion. It converts the energy of the fuel directly into electricity. In these cells, the reactants, products and electrolytes pass through the cell.



5. What are secondary cells?

In secondary cells, the electrode reactions can be reversed by passing an external electrical energy. Therefore, they can be recharged by passing electric current and used again and again. These are also called Storage cells or Accumulators.

Eg, Lead acid battery, Ni-Cd battery.

6. What are the applications of lead acid storage cell?

1. Lead storage cell is used to supply current mainly in automobiles such as cars, buses, and trucks.
2. It is also used in gas engine ignition, telephone exchanges, hospitals, power stations, etc.

7. What are the characteristics and uses of lithium ion cell ?

- (i) Li is a light-weight metal and high voltage batteries
- (ii) It is smaller in size.
- (iv) It produces three time the voltage of Ni-Cd batteries.
- (v) It has none of the memory effect seen in Ni-Cd batteries.

Uses: Cell phone, note PC, Portable LCD TV, Semiconductor driven audio etc

8. What are the limitations of H₂-O₂ Fuel cell?

- i) Hydrogen gas is explosive'
- ii) It is very expensive to be carried out
- iii) As hydrogen is a gas, it is difficult to compress into liquid form

9. Will the emf of battery vary with size? Give reason for your answer

No emf of a battery will not vary with size. Emf of a battery depends only on concentration and nature of anode and cathode

10. What are the electrodes used in the fuel cells porous?

Compressed carbon containing a small amount of catalyst like Pt,Pd,Ag are used in the fuel cells porous

11. What is Lithium Ion battery?

Lithium ion battery is a secondary battery. As in lithium cell, it does not contain metallic lithium anode .As the name suggests the movements of lithium ions are responsible for charging and discharging.

12. What are the components of LIB?

- A positive electrode –layers of lithium-metal oxide –cathode
- A negative electrode –layers of porous carbon –cathode
- An electrolyte –polymer gel-separator

13. What are the super capacitors?

Super capacitor is a high capacity capacitor with the capacitance value much higher than other capacitor. They store 10 to 100 times more energy per unit volume and deliver charge much faster than batteries.

14. Mention some important application of super capacitors

It is used in many power management applications like

- Voltage stabilization in start /stop system
- Energy Harvesting
- Kitchen appliances
- Regenerative breaking system

PART-B

1. What is reversible battery? Describe the construction and working of a lead storage battery with the reaction occurring during charging and discharging.
2. What is lithium battery? Give the reactions involved.
3. Describe the construction and working of hydrogen – oxygen fuel cell.
4. Write a note on super capacitor.
5. What are primary and secondary batteries ? Give examples.

LITHIUM ION CELL (PRIMARY)

Lithium ion battery is a secondary battery which consists normally 1.5V, 1.8V or 3.6V. It is responsible for charging and discharging. It consists of anode, cathode, electrolyte, separator, and a polymer gel.

Anode (-) → Porous carbon (or) graphite
 $\text{C} \rightarrow \text{C} + \text{e}^-$ (negative electrode)

Cathode (+) → Lithium metal oxide
 $\text{Li} \rightarrow \text{Li} + \text{e}^-$ (positive electrode)

Electrolyte → Polymer gel (organic solvent)

Cell representation - $\text{C} \parallel \text{Li}^+ \parallel \text{Polymer gel} \parallel \text{Li}^+ \parallel \text{LiO}_2$

Advantages:

Characteristics	Disadvantages
Li^+ flow from (+) electrode to (-) electrode through electrolyte	Li^+ flow from (-) electrode to (+) electrode through electrolyte
Electrons also flow from (+) to (-) through external circuit	Electrons also flow from (-) to (+) through external circuit
$\text{C} \rightarrow \text{C} + \text{e}^-$ (at -ve electrode)	$\text{Li} \rightarrow \text{Li} + \text{e}^-$ (at +ve electrode)
$\text{Li} \rightarrow \text{Li} + \text{e}^-$	$\text{Li} \rightarrow \text{Li} + \text{e}^-$

LEAD STORAGE CELL

ANODE - Pb
 CATHODE - PbO₂
 Electrolyte - dil. H₂SO₄ (aqueous)
 CELL VOLTAGE - 2 - 2.1 Volts

Cell representation:
 $\text{Pb} \parallel \text{PbSO}_4 \parallel \text{dil. H}_2\text{SO}_4 \parallel \text{PbO}_2 \parallel \text{PbSO}_4 \parallel \text{Pb}$

Cell reaction:
 At anode: Oxidation (release of e⁻)
 $\text{Pb} \rightarrow \text{Pb}^{2+} + 2\text{e}^-$

At cathode: Reduction (acceptance of e⁻)
 $\text{PbO}_2 + 4\text{H}^+ + 2\text{e}^- \rightarrow \text{Pb}^{2+} + 2\text{H}_2\text{O}$

Overall reaction:
 $\text{Pb} + \text{PbO}_2 + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$

Advantages:

- It provides three times the voltage of Ni - Cd batteries.
- It is smaller in size.
- It has none of the memory effect seen in Ni - Cd batteries.
- It has high voltage and low weight.

Applications:
 It is used in Laptop, TV, cell phone etc.

LEAD STORAGE CELL

ANODE - Pb
 CATHODE - PbO₂
 Electrolyte - dil. H₂SO₄ (aqueous)
 CELL VOLTAGE - 2 - 2.1 Volts

Cell representation:
 $\text{Pb} \parallel \text{PbSO}_4 \parallel \text{dil. H}_2\text{SO}_4 \parallel \text{PbO}_2 \parallel \text{PbSO}_4 \parallel \text{Pb}$

Cell reaction:
 At anode: Oxidation (release of e⁻)
 $\text{Pb} \rightarrow \text{Pb}^{2+} + 2\text{e}^-$

At cathode: Reduction (acceptance of e⁻)
 $\text{PbO}_2 + 4\text{H}^+ + 2\text{e}^- \rightarrow \text{Pb}^{2+} + 2\text{H}_2\text{O}$

Overall reaction:
 $\text{Pb} + \text{PbO}_2 + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$

Advantages:

- It is more costly.
- It has memory effect.
- It provides very high current.

Disadvantages:
 • It is not a secondary battery.
 • It is not a secondary battery.
 • It is not a secondary battery.

DIFFERENTIAL CAPACITOR

- It is a high capacity capacitor that can operate
- They are constructed from strips of foil separated
- They store energy from the battery
- To store electrical energy capacitor must be charged

Advantages

- High capacity (microfarad capacitor)
- It is a capacitor which is used in a circuit
- It is used to store energy
- It is used to store energy

Disadvantages

- It is used to store energy
- It is used to store energy
- It is used to store energy
- It is used to store energy
- It is used to store energy

See Diagram in Book
Pg. 10 - 11

Advantages

- It is a high capacity capacitor
- It is used to store energy
- It is used to store energy
- It is used to store energy

Disadvantages

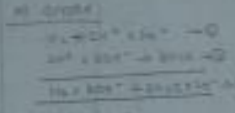
- It is used to store energy
- It is used to store energy
- It is used to store energy

Uses

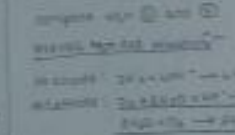
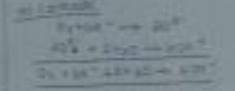
- It is used to store energy
- It is used to store energy
- It is used to store energy

FUEL CELL

ANODE: H_2
CATHODE: O_2
ELECTROLYTE: KOH
TEMP: $25^\circ C$



Multiply by 2
 $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$



Advantages

- It is used to generate electricity
- It is used to generate electricity

Disadvantages

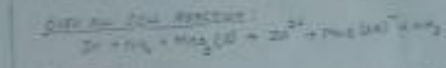
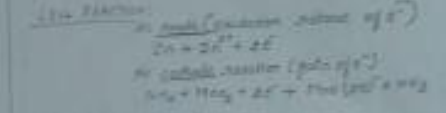
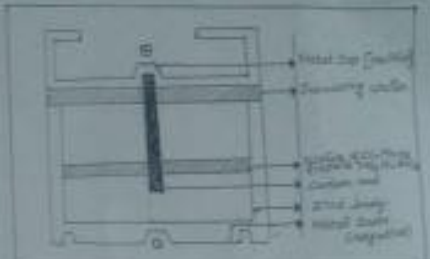
- It is used to generate electricity
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- It is used to generate electricity

Applications

- It is used to generate electricity
- It is used to generate electricity
- It is used to generate electricity

CELL WITH DIFFERENTIAL CAPACITOR

ANODE: H_2
CATHODE: O_2
ELECTROLYTE: KOH
TEMP: $25^\circ C$



- It is used to generate electricity
- It is used to generate electricity
- It is used to generate electricity

Advantages

- It is used to generate electricity
- It is used to generate electricity

UNIT I - WATER TECHNOLOGY-PART - A

1. Define hard water and soft water.
2. How is hardness of water detected?
3. Explain temporary and permanent hardness of water.
4. Why CaCO_3 is used as standard for expressing hardness? Give the units of hardness.
5. Sample water contains 16.8 mgs of MgCO_3 and 8.1 mgs of $\text{Ca}(\text{HCO}_3)_2$. Calculate the hardness in terms of CaCO_3 equivalent.
6. Draw the structure of EDTA and basic reaction (principle) of EDTA method.
7. Mention the units used for expressing hardness of water.
8. What are the requirements of boiler feed water?
9. What are the disadvantages using hard water in boiler or what are boiler troubles?
10. Define scale and sludge formation in boilers.
11. What is blow-down operation?
12. What are boiler compounds?
13. Distinguish between internal conditioning and external conditioning methods.
14. Distinguish between soft water and demineralised water or Demineralised water is soft water but Soft water is not Demineralised water. Why?
15. How is phosphate conditioning carried out?
16. Explain the chemical reaction involved in Calgon conditioning.
17. How is Sodium aluminate conditioning carried out
18. What is desalination?
19. What is Reverse osmosis?
20. What are the advantages of reverse osmosis method and limitations?

PART- B

1. Explain the estimation of hardness by EDTA method
2. What are the troubles caused by using hard water in boilers? or
3. Define external conditioning and explain the demineralization of water by ion-exchange process.
4. Describe zeolite process for water treatment.(6)
5. Explain internal conditioning of boiler feed water (8)
6. What is desalination? With a neat diagram describe reverse osmosis in detail.

UNIT-II SURFACE CHEMISTRY-PART-A

1. Differentiate adsorption and absorption.
2. Mention a few important characteristics of adsorption.
- 3 List the factors that affect adsorption.
4. Differentiate physisorption chemisorptions? Give an example.
5. What is meant by positive and negative adsorption?
6. Define adsorption isotherm.
7. Define Langmuir adsorption isotherm. Postulates
8. Define the terms adsorbent and adsorbate with suitable example.
9. Define catalysis and mention it types of catalysis with an example.
10. Define the term catalyst.
11. What are catalytic promoters?
12. What is meant by catalytic poisoning and types?
13. Define auto catalyst.
14. How an acid –base catalysis is carried out?
15. How do enzymes or biological as catalysis?
16. What is the role of adsorbent in catalysis?
17. What is turn over number.

PART-B

1. Differentiate physisorption and chemisorptions.
2. Describe the factors that influence adsorption of a gas on a solid.
3. Derive Freundlich's adsorption isotherm and state its limitations.
4. State the postulates and derive Langmuir adsorption isotherm and discuss it with various pressures.
5. Explain contact theory of catalysis or illustrate the role of adsorbents in ion exchange adsorption.

6. Derive the rate of a unimolecular reaction and bimolecular or Langmuir-Hinshelwood mechanism in a surface reaction.
7. Derive Michaelis –Menten equation from Enzyme and Substrate?
8. Outline the role of activated carbon in pollution abatement of water
9. Derive kinetics of acid basis catalysis of 1.First mechanism 2.second mechanism

UNIT-II – PHASE RULE & ALLOYS- PART – A

1. Define phase (P) with an example
2. What is component (C)? Give an example.
3. What is meant by degree of freedom (F)?
4. How many phases and components are there in following systems?
 - a) $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
 - b) $\text{NH}_4\text{Cl}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{HCl}(\text{g})$
 - c) $\text{MgCO}_3(\text{s}) \rightleftharpoons \text{MgO}(\text{s}) + \text{CO}_2(\text{g})$
 - d) $\text{PCl}_5(\text{S}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$ at 50oC
5. What is phase diagram? What are its uses?
6. Define phase rule.
7. State reduced phase rule (Or) condensed phase rule.
8. Differentiate melting point, eutectic point and triple point.
9. What is metastable equilibrium?
10. Define an alloy.
11. What is the significance of alloying?
12. What are the properties or objectives of alloys?
13. Define heat treatment of alloys
14. With an example discuss the types of alloys.
15. Give the composition and uses of Nichrome.
16. What is 18/8 stainless steel? What are its properties?

Part-B

1. State phase rule and explain the terms involved in it. (2+2+2+2 marks)
2. Draw and explain the phase diagram of one component system
3. What is reduced phase rule? Explain lead-silver system or binary alloy system or simple eutectic system in detail and application of pattinson processes.
- 4 Explain thermal analysis and cooling curves
5. Explain the types of heat treatment of alloys or steel. (8)
6. What are ferrous alloys? Explain the composition, properties and uses of important ferrous alloys.

UNIT –IV-FUELS AND COMBUSTION-PART-A

1. What is fuel?
2. Write the characteristics of a good fuel.
3. Define calorific value of fuel.
4. Write briefly on the ranking of coal.
5. Distinguish between coal and coke. (or)How coke is superior to coal?
6. What are caking and coking coal.
7. What are the characteristics of metallurgical coke? (AU 95)
8. What is carbonization indicate its different types? Or what is metallurgical coke?
9. Difference between Proximate and ultimate analysis
10. What are the draw backs of presence of sulphur in the coal? (2014)
11. What is cottrell's process in crude oil refining?
12. What is knocking? How will you improve the anti knocking properties of petrol?
13. Define octane number of a gasoline? How it can be improved?
14. Define cetane number of diesel oil?
15. What is CNG? Give its constituents.(Dec-09)
16. What is LPG? Write its composition and uses
17. What is power alcohol? Mention the advantage.
18. Define Bio diesel.
19. Differentiate gross and net calorific value of a fuel. (Jan-08)
20. What is ignition temperature and spontaneous ignition temperature?
20. Mention the significance of flue gas analysis.
21. Name the reagents used in flue gas analysis. Indicate their importance.
22. Define explosive range of a fuel.(AU 2014)

PART-B

1. Discuss briefly proximate analysis of coal and their significance.
2. Describe about ultimate analysis and its significance.
3. Describe the Otto- Hofmann method of coke manufacture and the recovery of various by-products.
(Or) Describe the manufacture of Metallurgical Coke. (Dec-08)
4. What is meant by crude petroleum? Discuss the principle steps in the refining of crude petroleum.
5. Describe the different methods by which synthetic petrol can be obtained (Bergius process). (Dec-06)
6. What is meant by Knocking in petrol engines? How is knocking prevented?
7. Explain the following (i) Compressed naturalgas (CNG) (ii) Liquid petroleum gas. (LPG)
8. Explain how the flue gas analysis is carried out by using Orsat's apparatus method with a neat diagram.

UNIT – V ENERGY SOURCES

SECTION – A

1. Define nuclear fission.
2. What is nuclear fusion? Give an example.
3. Differences between nuclear fission and nuclear fusion reactions
4. What is neutron multiplication factor?
5. What is nuclear chain reaction?
6. What is super critical mass and sub-critical mass of U 235?
7. What is nuclear energy?
8. What are the drawbacks of nuclear energy?
9. What are thermo nuclear reactions? Give one example.
10. Mention the factors that hinder the nuclear chain reaction.
11. What is a nuclear reactor?
12. What is light water nuclear – power plant?
13. What are moderators? Give some examples.
14. What is Breeder reactor?
15. What is fissile and fertile nucleides?
16. Mention any two differences of a nuclear reaction and chemical reaction.
17. What is meant by solar energy conversion? How is it done?
18. What is photo galvanic cell or solar cell? (AU-08/09)
19. Explain the applications of solar cells.
20. What is Wind energy? How is it obtained?
21. What are the drawbacks of wind energy?

PART -B

1. State any four characteristics of nuclear fission reaction. (AU – 09)
2. What are nuclear chain reactions? Explain how the amount of nuclear energy can be improved. (AU – 13)
3. Give an account of light water nuclear power plant with a neat diagram.
4. Describe the breeder reactor. (AU – 10)
5. State the principle and applications of solar batteries. (AU – 08&13)
6. Write a note on wind energy. (AU – 09)

BATTERIES

1. What is a battery? How does it differ from a cell? (AU-09)
2. What are the important requirements of a battery?
3. What is a primary battery? Give an example. (AU-Jan-10)
4. What are fuel cells? (AU-08/09)
5. What are secondary cells?
6. What are the applications of lead acid storage cell?
7. What are the characteristics and uses of lithium ion cell?
8. What are the limitations of H₂-O₂ Fuel cell?
9. Will the emf of battery vary with size? Give reason for your answer
10. What are the electrodes used in the fuel cells porous?
11. What is Lithium Ion battery?
12. What are the components of LIB?
13. What are the super capacitors?
14. Mention some important application of super capacitors

PART-B

1. What is reversible battery? Describe the construction and working of a lead storage battery with the reaction occurring during charging and discharging.
2. What is lithium battery? Give the reactions involved.
3. Describe the construction and working of hydrogen – oxygen fuel cell.
4. Write a note on super capacitor.
5. What is primary battery, Give an Example?