**PVP 23**

Code: 23BS1204

**I B.Tech - II Semester – Regular / Supplementary Examinations**
**JUNE 2026**

# ENGINEERING CHEMISTRY

**(Common for CE, ME)**

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

## PART – A

| | | BL | CO |
|---|---|---|---|
| 1.a) | What is permanent hardness? | L2 | CO1 |
| 1.b) | Explain Priming and Foaming in boiler troubles. | L2 | CO2 |
| 1.c) | Define batteries and give their classification. | L3 | CO2 |
| 1.d) | Mention pilling Bedworth ratio for protective behavior of oxides. | L2 | CO2 |
| 1.e) | Define Functionality and give their significance. | L2 | CO1 |
| 1.f) | Give Dulong's formulae for HCV calculation. | L2 | CO1 |
| 1.g) | Briefly explain the classification of refractories. | L2 | CO3 |
| 1.h) | Discuss the applications of fibre reinforced composites. | L3 | CO3 |
| 1.i) | Discuss the applications of colloids. | L2 | CO3 |
| 1.j) | Explain the Braggs method for colloids synthesis. | L2 | CO3 |

## PART – B

| | | | BL | CO | Max. Marks |
|---|---|---|---|---|---|
| **UNIT-I** | | | | | |
| 2 | a) | List the specifications for portable water according to the Bureau of Indian Standards (BIS). | L3 | CO2 | 5 M |
| | b) | Distinguish between scale and sludge in boiler troubles. | L4 | CO4 | 5 M |
| **OR** | | | | | |
| 3 | a) | Describe the estimation of dissolved oxygen to determine hardness of water. | L4 | CO4 | 5 M |
| | b) | Make use of a neat diagram to explain electro-dialysis process. | L3 | CO2 | 5 M |
| **UNIT-II** | | | | | |
| 4 | a) | Derive Nernst Equation and give its applications. | L3 | CO2 | 5 M |
| | b) | Explain metal oxide formation by chemical corrosion. | L4 | CO4 | 5 M |
| **OR** | | | | | |
| 5 | a) | Explain construction, working principle & applications of Zinc-air batteries. | L4 | CO4 | 5 M |
| | b) | Discuss Impressed current cathodic protection for corrosion. | L3 | CO2 | 5 M |
| **UNIT-III** | | | | | |
| 6 | a) | Explain free radicle addition polymerization for Vinyl chloride. | L4 | CO4 | 5 M |

| | | | | | |
|---|---|---|---|---|---|
| | b) | Discuss ultimate analysis of coal and give their significance. | L3 | CO2 | 5 M |
| **OR** | | | | | |
| 7 | a) | Discuss the stepwise synthesis procedure of Bakelite using step growth polymerization. | L3 | CO2 | 5 M |
| | b) | Explain Octane number and Cetane number and give their significance. | L4 | CO4 | 5 M |
| **UNIT-IV** | | | | | |
| 8 | a) | Define composites and mention properties and engineering applications of Fiber reinforced composites. | L3 | CO3 | 5 M |
| | b) | Distinguish flash point and fire point of lubricants. | L4 | CO5 | 5 M |
| **OR** | | | | | |
| 9 | a) | Discuss the mechanism involved in setting and hardening of Portland cement. | L3 | CO3 | 5 M |
| | b) | Mention the Properties, Applications and factors affecting the refractory materials. | L4 | CO5 | 5 M |
| **UNIT-V** | | | | | |
| 10 | a) | Define colloids and mention their applications in catalysis, medicine, and sensors. | L3 | CO3 | 5 M |
| | b) | Explain green synthesis of Gold Nanoparticles Using Neem Leaf Extract. | L4 | CO5 | 5 M |
| **OR** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 11 | a) | Make use of neat diagram to explain the synthesis of Nanomaterial using Sol-gel method. | L3 | CO3 | 5 M |
| | b) | Explain Freundlich and Longmuir adsorption isotherm curves to demonstrate adsorption mechanism. | L4 | CO5 | 5 M |

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## PART – A

1(a). What is permanent hardness?

Definition-2M

1(b). Explain Priming and Foaming in boiler troubles.

Priming -1M Foaming-1M

1(c). Define batteries and give their classification.

Define battery-1M classification-1M

1(d). Mention Pilling–Bedworth ratio for protective behavior of oxides.

Tw conditions- 2M

1(e). Define Functionality and give their significance.

Define Functionality-1M

Significance-1M

1(f). Give Dulong's formula for HCV calculation

Dulong's formula-2M

1(g). Briefly explain the classification of refractories.

Classification-2M

1(h). Discuss the applications of fibre reinforced composites.

Applications-2M

1(i). Discuss the applications of colloids.

Applications of colloids-2M

1(j). Explain the Bragg's method for colloids synthesis.

Bragg's method for colloids synthesis-2M

## PART – B

### UNIT – I

2(a). List the specifications for potable water according to the Bureau of Indian Standards (BIS).

List the specifications for potable water-5M

**OR**

2(b). Distinguish between scale and sludge in boiler troubles.

Distinguish between scale and sludgeS-5M

3(a). Describe the estimation of dissolved oxygen to determine hardness of water.

Principal &estimation-5M

**OR**

3(b). Make use of a neat diagram to explain the electro-dialysis process.

Definition of electro-dialysis-1M

Explaination-2M

Diagram-1M

**UNIT – II**

4(a). Derive the Nernst equation and give its applications.

Derive the Nernst equation-3M

Applications-2M

**OR**

4(b). Explain metal oxide formation by chemical corrosion.

Explanation-5M

5(a). Explain the construction, working principle and applications of Zinc-air batteries.

Construction-2M working principle -2M applications- 1M

**OR**

5(b). Discuss impressed current cathodic protection for corrosion.

Explanation-4M Diagram-1M

**UNIT – III**

6(a). Explain the free radical addition polymerization for Vinyl chloride.

3STEPS- 5M

**OR**

6(b). Discuss ultimate analysis of coal and give their significance.

ultimate analysis of coal-4M

Significance-1M

7(a). Discuss the stepwise synthesis procedure of Bakelite using step-growth polymerization.

Prcedure-2M

STEPS-3M

**OR**

7(b). Explain octane and cetane number and give their significance.

Definitions -3M

Significance-2M

**UNIT – IV**

8(a). Define composites and mention the properties and engineering applications of Fibre Reinforced Composites.

Properties-2M

engineering applications-3M

OR

8(b). Distinguish flash point and fire point of lubricants.

Differences-5M

9(a). Discuss the mechanism involved in setting and hardening of Portland cement.

Definitions-2M reactions-2M process-1M

OR

9(b). Mention the properties, applications and factors affecting refractory materials.

Properties-2M applications- 2M factors affecting refractory materials-1M

UNIT – V

10(a). Define colloids and mention their applications in catalysis, medicine and soaps.

Define colloide-1M applications in catalysis, medicine and soaps-4M

OR

10(b). Explain green synthesis of Gold Nanoparticles using Neem leaf extract.

green synthesiS-5M

11(a). Make use of a neat diagram to explain the synthesis of nanomaterial using Sol-Gel method.

Diagram-1M

explain the synthesis of nanomaterials-4M

OR

11(b). Explain Freundlich adsorption isotherm and Langmuir adsorption mechanism.

Freundlich adsorption isotherm-2.5M Langmuir adsorption mechanism-2.5M

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**PART – A (2 Marks)**

**1(a) What is permanent hardness? (2 Marks)**

**Answer**: Permanent hardness is the hardness of water caused by the presence of calcium and magnesium chlorides and sulphates. It cannot be removed by boiling. It can be removed by zeolite or ion-exchange methods.

**1(b) Explain Priming and Foaming in boiler troubles. (2 Marks)**

**Answer:**

Priming: Carrying of water droplets along with steam due to rapid boiling or high water level.

Foaming: Formation of stable bubbles on the boiler water surface due to the presence of oil or grease.

**1(c) Define batteries and give their classification. (2 Marks)**

**Answer:** A battery is a device that converts chemical energy into electrical energy.

Classification:

Primary batteries (Non-rechargeable)

Secondary batteries (Rechargeable)

Fuel cells

**1(d) Mention Pilling–Bedworth ratio for protective behaviour of oxides. (2 Marks)**

**Answer:** The Pilling–Bedworth Ratio (PBR) is the ratio of the volume of oxide formed to the volume of metal consumed.

PBR < 1: Non-protective oxide layer.

PBR > 1: Protective oxide layer.

**1(e) Define Functionality and give its significance. (2 Marks)**

**Answer:** Functionality is the number of reactive groups present in a monomer molecule.

**Significance:**

Determines the type of polymer formed.

Decides whether the polymer is linear, branched, or cross-linked.

**1(f) Give Dulong's formula for HCV calculation. (2 Marks)**

**Answer:**

HCV = 1/100 [8080C + 34500(H − O/8) + 2240S] kcal/kg

Where:

C = % Carbon

H = % Hydrogen

O = % Oxygen

S = % Sulphur

**1(g) Briefly explain the classification of refractories. (2 Marks)**

**Answer:** Refractories are classified into:

Acidic refractories – Resist acidic slags.

Basic refractories – Resist basic slags.

Neutral refractories – Resist both acidic and basic slags.

**1(h) Discuss the applications of Fibre Reinforced Composites. (2 Marks)**

**Answer:**

**Applications:**

Aircraft and spacecraft.

Automobile parts.

Construction materials.

Sports equipment.

Marine industries.

**1(i) Discuss the applications of colloids. (2 Marks)**

**Answer:** Applications:

Water purification.

Medicines.

Paints and inks.

Food products.

Rubber and textile industries.

**1(j) Explain Braggs method for colloids synthesis. (2 Marks)**

**Answer**: The term "Bragg's Method" refers to the measurement and analysis of crystal structures and nanoparticle sizes using **Bragg's Law** of diffraction (\(n\lambda = 2d \sin\theta\)). In colloidal synthesis, it involves characterizing the uniform spacing of colloidal particles (such as opal crystals) or using small-angle X-ray scattering (SAXRD) to determine the size and lattice constants of synthesized nanoparticles.

**PART -B**

**2(a). List the specifications for potable water according to BIS. (5 Marks)**

**Answer:**

- Drinkingwatershouldbecolourlessandodourless.
- Itshouldbegoodintasteandshouldnotbehot.
- Itshouldbefreefromalltypesofpathogenicmicroorganisms.
- Totalhardnessshouldnotexceed300ppmand turbidityshouldbelessthan10 ppm.
- It shouldnot behighlyalkaline(pHcanbe6.5-8.5).
- Freeresidualchlorine canbe up to0.2 ppmand totaldissolved solidsupto500ppm.
- Itshouldbefreefromobjectionablegaseslike$H_2S$andmineralsaltsoflead,chromium,cadmium ,arsenicandmanganese.
- Themaximumlimitoffluorideis1.5ppm,arsenic0.01ppmandlead0.05ppm.,pb0.1.
- CODandBOD limitsare250mg/litand10mg/litrespectively.

**2(b). Distinguish between Scale and Sludge in Boiler Troubles. (5 Marks)**

**Answer:**

**Scale** and **sludge** are two common boiler troubles caused by the impurities found in hard feed water. Sludge refers to soft, slimy, and loosely suspended precipitates that collect in the colder, low-flow areas of the boiler. Conversely, scale consists of hard, strongly adherent crusts that deposit on the hotter, high-heat surfaces. A clear, point-by-point distinction between the two is summarized below:

| | Sludge | Scale |
|---|---|---|
| **Nature** | Soft, loose, and slimy. | Hard, strong, and highly adherent. |
| **Location** | Tends to settle in colder parts and bottom of the boiler (e.g., mud drum). | Deposits firmly on hotter regions (e.g., boiler tubes and heating surfaces). |
| **Chemical Formation** | Formed by salts that have *greater* solubility in hot water than in cold water (e.g., $MgCl_2$, $CaCl_2$). | Formed by salts with limited or *decreasing* solubility at high temperatures (e.g., $CaSO_4$, $CaCO_3$). |
| **Danger Level** | Relatively less harmful. It can act as a mild insulator, but doesn't instantly threaten structural integrity. | Highly dangerous. Acts as a thermal insulator, leading to severe localized overheating, metal fatigue, and potential explosions. |
| **Removal Method** | Easily removed by regular **blow-down** operations (draining sludge from the bottom). | Very difficult to remove; typically requires mechanical scraping, thermal shock, or chemical treatments (like acids). |
| **Prevention** | Mitigated by softening feed water and frequent blow-down. | Prevented by thorough external water softening (e.g., Zeolite process) and internal chemical conditioning. |

**3(a). Describe the estimation of dissolved oxygen in water. (5 Marks)**

**Answer: EstimationofDissolvedoxygen:**

DissolvedoxygenisdeterminedbyWinkler'smethod(or)Idometrictitrations.

Principle:ItisbasedonthefactthatoxygendissolvedinwateroxidizesKIandanequivalent amount of Iodine is liberated. The liberated Iodine is titrated against standard hyposolution using starch as indicator. However since oxygen is in molecularstate in water it isnotcapable of reactivity with KI, soan oxygen carrier such as Mn(OH)2is used. ItisproducedbytheactionofMnSo4withKOH.

$$2KOH+MnSO_4 \rightarrow Mn(OH)_2+K_2SO_4$$

$$2Mn(OH)_2 \quad +O_2 \quad \rightarrow \quad 2MnO(OH)_2$$

(Oxygencarrier) (Basicmagneticoxide)

Procedure:

A Known amount of water sample water (250 ml) is taken in a stoppered bottle avoidingcontact with air.2 ml of MnSO4is added similarly 2 ml of alkaline azide solution is added.The bottle is stoppered and shaken thoroughly. The brown precipitate so formed is dissolvedinminimum quantity of concentratedH2SO4. Thebottleisshakenwell todissolvetheprecipitate. 100ml of this solution is then titrated against hypo solution using freshly preparedstarch as an indicator. The disappearance of blue colour marks the end point. Let the volumeofhyposolutionusedbeVml.

Calculation:

1000mlof1Mhyposolution≅8gofoxygen

X mlofYMhyposolution≅$\frac{XxYx8}{1000}$ gofoxygen

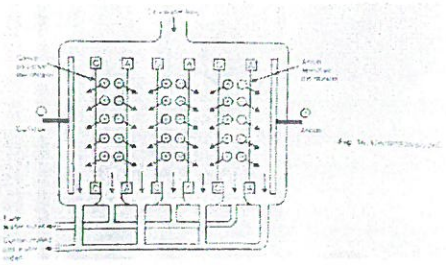
i.e.,theamountofoxygenpresentin100mlofwatersample=XxYx8mg

=$\frac{XxYx1000x8}{100}$

=X xYx80mg

**3(b). Explain the Electro-dialysis Process with a neat diagram. (5 Marks)**

**Answer:Electro dialysis:** Electro dialysis is based on the fact that the ions present in saline water migrate towards their respective electrodes, through ion - selective membranes (natural or synthetic) under the influence of applied emf.



**Electrodialysis**

In this method ions are attracted towards anode and cathode on passing electricity through saline water.The ions pass through ion selective membrane towards the direction of the opposite electrodes.As a result containers witheven number are filled with the purewaterandthecontainerswithoddnumberarewithconcentratedbrinesolution.Theion-selective membrane pores are lined with fixed charge, which exclusively permit flow of only one type ions through the pres and rejects the opposite charged ions. The cation selective membranes and the anion selective membranes are alternatively placed to make separate containers. On passing a direct current the containers between cation and anion selective membrane will have pure water, since both the cations and anions leave out through the ion selective membrane in the opposite direction.

The ion selective membranes are generally polystyrene based polymers containingsulfoni acid (cation selective) and tetrammonum chloride (anion selective

**Advantages of Electrodialysis**

- **High Water Recovery:** Highly efficient, especially in specific brackish water and industrial reuse setups.
- **Low Pressure:** Unlike Reverse Osmosis (RO), ED operates at very low pressures, significantly reducing membrane fouling.
- **No Phase Change:** Because no boiling or evaporation is required, energy consumption remains relatively low.

**UNIT – II**

**4(a). Derive the Nernst equation and give its applications. (5 Marks)**

**Answer:Definition:**

The Nernst equation is used to calculate the electrode potential of an electrode under non-standard conditions.

The Nernst equation establishes a relationship between an electrochemical cell's potential and the concentrations (or activities) of the reactants and products. It allows engineers and chemists to calculate cell potentials and single electrode potentials under non-standard conditions

**Derivation of the Nernst Equation**

**Nernst Equation:**

Suppose the cell reaction involved in any reversible cell, which is represented by the given equation

$$aA + bB \rightarrow xX + yY$$

The free energy change of this reaction is given by the equation.

$$\Delta G = \Delta G^o + RT \ln \frac{aX^x \cdot aY^y}{aA^a \cdot aBb}$$

aA,bB,aX, &aY represents the activities of A,B,X,&Y respectively in any state.

If the cell reaction involves transference of 'n' moles of electrons, this corresponds to flow of 'nF' faradays of electricity.

If 'E' is the EMF of the cell, then the electrical energy produced in the cell = nFE

Since electrical energy produced is equal to the decrease in the free energy of the cell reaction, we have.

$$-\Delta G = nFE \text{ ----------2}$$

Similarly for the standard state, we will have

$$-\Delta G^o = nFE^o \text{ ----------3}$$

Where $E^o$is the standard EMF of the cell

Substituting the values of $\Delta G$& $\Delta G^o$ from the equations 2&3 in 1 we get,

$$-nFE = -nFE^o + RT \ln \frac{aX \cdot aY^y}{aA^a \cdot aBb}$$

Divide the equation 4 with '$-nF$'

$$E = E^{\circ} - \frac{RT}{nF} \ln \frac{a_X^x \cdot a_Y^y}{a_A^a \cdot a_B^b}$$

Thus knowing the cell reaction and the standard EMF of the cell ' $E^{o}$ ' ,the EMF of the cell for known activities of the various reactants and products can be calculated.

Equation '5' is known as "Nernst equation", which is useful for the calculation of EMF of the cell.

When the concentrations are very dilute, activities can be replaced by concentrations. Then, equations "5" becomes

$$E = E^{\circ} - \frac{RT}{nF} \ln \frac{[X]^x \cdot [Y]^y}{[A]^a \cdot [B]^b}$$

Where, R= 8.314 joule $joles.deg^{-}mole^{-}$

F = 96,500 coulombs T = 298Kat25°

It must be born in mind that the activities or concentrations of the pure liquids or pure solids are taken as unity.

**Applications of Nernst Equation:**

- Nernst equation can be used to study the effect of electrolyte on electrode potential.
- It can be used for calculation of the potential of a cell under standard conditions.
- Used for determination of unknown concentration.
- Used for the determination $P^{H}$ from the measurement of EMF.
- Used for the determination of valancyof an ions or number of electrons involved in electrode reaction.

**4(b). Explain metal oxide formation by chemical corrosion(5 Marks)**

- **Answer:** **Oxygen corrosion** :This occurs due to the direct attack of oxygen on the surface of the metalin the absence of moisture at low or high temperature .As a result, metal gets transformed into its oxide.Most of the metals except Ag,Au and Ptundergo oxidativecorrosion at hightemperature

$$4Fe + 3O2 \longrightarrow 2Fe2O3$$

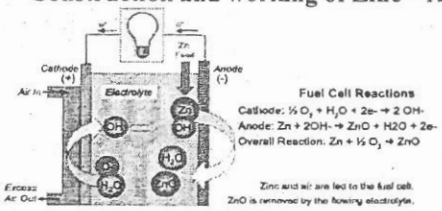
Thenatureofthemetaloxidedetermineswhetherametalfurtherundergoescorrosionornot.Theoxide formed maybestable, unstable, volatile, or porousand non protective.

- **Stable,protectiveandnonporousoxidefilm**:Theoxidefilmformedmaybestable,homogeneous,im perviousandtightly adheringtothesurfaceofthemetal.Suchanoxideprotectsthemetal from furthercorrosion. example: Al, Cr, Cu, W etc.
- **Unstable oxide film**: The oxide film formed may be sometimes unstable. If so it undergoes decomposition to give back the metal and oxygen. Such oxide film slows down the corrosion orcompletely stops the corrosion .This is thereasonwhy gold and platinum donotunder go corrosion.
- **Volatile oxide film**: The oxide film formed may be volatile. As such it gets volatilized the moment it is formed leaving the surface of the metal free for further corrosion. Molybdenum thusundergoes excessive corrosion due to the formation of volatile MoO3.
- **Porous and non protective oxide film**: The oxide film formed may be porous .In such conditions it allows the diffusion of oxygen through its pores to reach the metal where corrosion occurs further . **Eg:alkaliandalkalinemetals.**

**5(a). Explain the construction, working and applications of Zinc-Air Battery. (5 Marks)**

**Answer**: Many commercial batteries are not able to meet the requirements of many applications. These modern batteries are introduced with improved characteristics like (long life ,low cost little or no maintenance and safety.
E.g.: Zinc – Air battery

**Construction and working of Zinc – Air battery:**




Anode - Amalgamated Zinc powder
Cathode – Air|C
Electrolyte - KOH
6M
**Representation of Zinc – Air battery: Zn| KOH|| Air C**

- Zinc – Air battery is a primary battery i.e. non-rechargeable and the reaction is irreversible.
- It is also known as alkaline battery.

- In this battery the cathode is made up of porous carbon plate which activated by manganese oxide. Anode is made up of rectangular An pellets which are placed between two cathodes.
- Because it is alkaline battery we can use wither KOH or Noah as an electrolyte. But we have to use KOH only as the ionic conductance of KOH is higher than Noah.
- The electrodes are separated by gascade insulating material. The whole assembly is Enclosed in glass or ebonite container coated with Teflon, which is hydrophobic i.e. it Allows only oxygen but not moisture.
- At cathode the electro active species air i.e. oxygen. During the cell reactions in battery the electrolyte concentrations is remains constant.

The reactions occur are as follows:

At anode: At anode the Zn undergoes oxidation in presence of electrolyte to produce zinc oxide and eater.

$$Zn+2OH^- \longrightarrow ZnO+H2O+2e^-$$

At cathode, water undergoes reduction reaction in presence of oxygen and electrons to give up hydroxyl ions, So the OH - ions consumed at anode and liberated at cathode, hence the overall concentration of electrolyte is constant.

$$1/2\ O2 + H2O + 2e^- \longrightarrow 2OH^-$$

The overall reaction is $Zn+ 1/2\ O2 \longrightarrow ZnO$

The output of the Zn-air battery is 1.65V

**Advantages:**

- High energy density.
- Low cost
- Capacity is independent of load and temperature.

**3. Applications**

Because these batteries are lightweight, inexpensive, and offer highly stable voltage, their applications include: [1, 2]

Medical Devices

Telecommunications

Military and Traffic

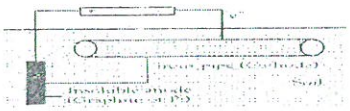
Grid Storage

Medical devices

Navigation lights

**5(b). Discuss Impressed Current Cathodic Protection. (5 Marks)**

**Answer:Impressed current cathodic protection**: In this method the metallic object to beprotected is made cathode by connecting it to the negative terminal of DC source. Whereasitspositiveterminal isconnectedtoaninsolubleanodelikegraphiteorplatinum.Nowelectrons flow to the metallic object hence it acts as a cathode and is protected fromcorrosion.



**However there are certain problems and limitations in applying catholic protection method.**

- The cathodic protection may increase the corrosion of an adjacent pipe line because of straycurrent(portion of the current that flows over a path other than the intended path and may causeelectrochemical corrosion of metals in contact withelectrolytes)
- Thismethodneedscapitalinvestmentandmaintenancecost.
- Chemical reactions taking place on the surface of the protective structure may cause certainproblems. For example if hydrogen is produced due to cathodic reactions, it may cause blisteringonthe surfaceof the cathodemetal.

Though the metal is protected by the above methods underground structures may be effected bymicrobiologicalcorrosion.

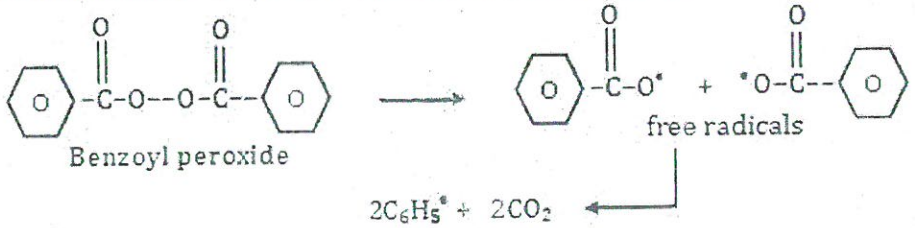
**UNIT – III (5 Marks Each)**

**6(a). Explain the Free Radical Addition Polymerization of Vinyl Chloride. (5 Marks)**

Answer:**Mechanism of polymerization Freeradicalpolymerization**

In this type of polymerization monomeris activated to free radical by anyone of the following methods.

- Photochemicalinitiation:- Byexposingto sunlight freeradicalsare generated.
- Thermalinitiation:-Byheating freeradicalsaregenerated.
- Radiationinitiation:-Byexposingto□,□or□-raysfreeradicalsaregenerated.




- Chemical initiation:- By using initiators like peroxides free radicals are generated. Benzoyl peroxide or Azobisisobutyronitrile, persulphates etc are used as chemicalinitiators. Mechanism of freeradicalpolymerization involves threesteps.

- **Chaininitiation:-**

Itinvolvestwosteps.

- Formation of freeradicals fromthe initiator.




- Additionoffreeradicalstomonomertoforma freeradicalintermediate.


- **Chainpropagation:-**

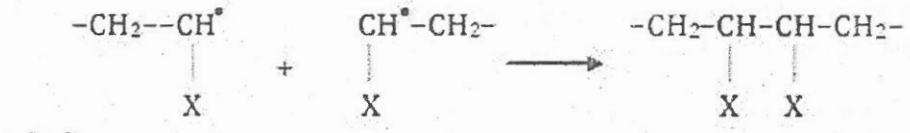
Hereadditionofmonomermoleculestotheintermediatetakesplaceonebyoneleadstothe formation of


- **Chaintermination:-**

Thegrowingpolymerchainis terminated bymanyways.

- Recombination:-

Combination oftwo freeradicals leads totermination.

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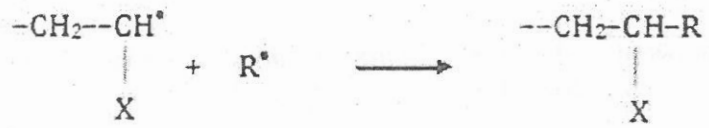



At 60°C polystyreneor Acrylonitrilechainsterminate mainlybyrecombination.

- Disproportination:-

Transferof'H'atomfromoneradicaltoanotherleadstoformationoftwomacromoleculesone of themwith a double bond.

**6(b). Discuss the Ultimate Analysis of Coal and its Significance. (5 Marks)**

**Answer:**

- **Ultimate Analysis**: It involves determination of elemental composition of the coal. The elements analysed are carbon, hydrogen, nitrogen, sulphur, oxygen as well as ash content. These results areusefulincalculatingthecalorificvalueofcoalusingDulong'sformula.

- *Carbon and Hydrogen*: About 1-2 grams of accurately weighed coal sample is burnt in a current ofoxygen in a combustion apparatus. Carbon and hydrogen of the coal are converted into CO2 and H2Orespectively. These gaseous products of combustion are absorbed respectively in KOH and CaCl2tubes of known weights. The gain in weights of thesetubes is determined to calculate percentagesofC andH.

**C+O2CO2(12 parts by weight of C gives 44 parts by weight of CO2)H2 +½O2 H2O**

**(2 parts by weight of H gives 18 parts by weight of H2O)2KOH+CO2K2CO3+H2O**

$$CaCl_2 + 7H_2O \quad CaCl_2.7H_2O$$

Increase in weight of KOHtubeis duetoCO2produced duringcombustion and henceit givespercentage of carbon in the coal. Similarly, increase in weight of CaCl2 tube is due to H2O producedandhenceit correspondstopercentageofhydrogen.

$$\text{Carbon (\%)} = \frac{\text{Increase in weight of KOH tube x 12 x 100}}{\text{Weight of coal sample taken x 44}}$$

$$\text{Hydrogen (\%)} = \frac{\text{Increase in weight of } CaCl_2 \text{ tube x 2 x 100}}{\text{Weight of coal sample taken x 18}}$$

Higher the percentages of carbon and hydrogen, better the quality of coal and higher its calorificvalue.Percentageofcarbonishelpful inassessingtherankofthecoal.

- *Nitrogen*: Nitrogen present in a coal sample is determined by the Kjeldahl method. About 1 gramof the finely powdered coal sample is heated with conc. H2SO4 along with the catalyst K2SO4 in a longnecked flask called Kjeldahl flask. Nitrogen in the coal gets converted to ammonium sulphate and a clear solution is obtained.

$$2N + 3H_2 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

**Then it is heated with excess of NaOH and liberated ammonia is distilled over and absorbed in aknownvolumeofstandardacidsolution.**

The unused acid is then determined by back titration with standard NaOH solution, from which acidneutralized by the liberated ammonia is calculated. From this, percentage of nitrogen in coal iscalculatedasfollows.

$$\text{Nitrogen (\%)} = \frac{\text{Volume of acid used x Normality of acid x 1.4}}{\text{Weight of coal taken}}$$

**Nitrogen does not contribute to calorific value of coal and hence its presence is undesirable in coal.Hence,goodqualitycoalhaslessnitrogencontent.**

- *Sulphur*: Sulphur present in a coal sample is determined by Eschka method. In this method,sulphur present in coal is converted into soluble (sodium) sulphate by incinerating known weight ofcoal with a 1:2 mixture of Na2CO3and calcinated MgCO3in a bomb calorimeter. The washingsobtained from bomb are treated with barium chloride solution so that sulphates are precipitated asBaSO4.The precipitate is filtered, washed and heated to constant weight.

$$\text{Sulphur (\%)} = \frac{\text{Weight of } BaSO_4 \text{ obtained x 32 x 100}}{\text{Weight of coal sample taken in bomb x 233}}$$

Sulphur increases the calorific value of coal. But, it produces acidic combustion products (SO2andSO3) which have corrosion effects on metallic equipment as well as these harmful gases cause air pollution. Good quality coal contains low sulphur content.

- *Ashcontent*:Determinationofashcontent iscarriedoutasinproximateanalysis.

- *Oxygen*: It is obtained by subtracting percentages of all the elements and ash content determinedabove,from100.

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

Coals containing high oxygen content are characterized by high inherent moisture and low calorificvalue. As oxygen is present in combination with hydrogen, in the form of water, hydrogen

availablecombustion is lesser than actual one. Thus, a good quality coal should have low percentage ofoxygen.

**7(a). Discuss the Step-Growth Polymerization (Preparation of Bakelite). (5 Marks)**

Answer:

**Condensationpolymerization:**

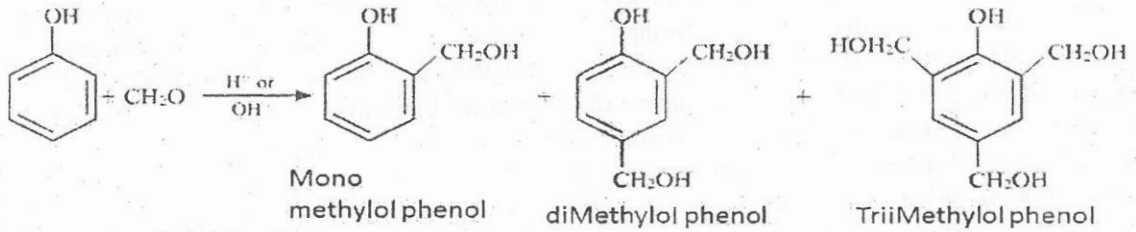
Polymerisformedbytwoormoremonomersbytheeliminationofsmallmolecules.Byproductsare formed likeH2O,NH3

Monomers with functional group undergo condensation polymerisation.Ex:BAKELITE

**STEP GROWTH POLYMERIZATION MECHANISM**

**Step-1**

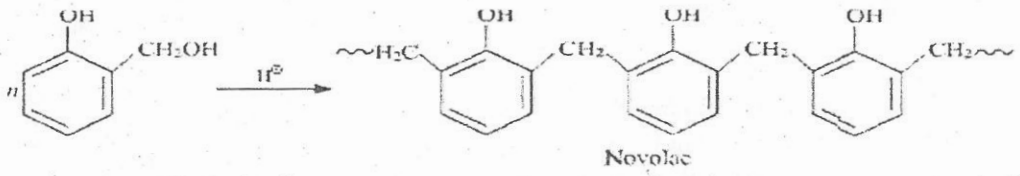
The first step is reaction between phenol and formaldehyde to form mono, di and tri-



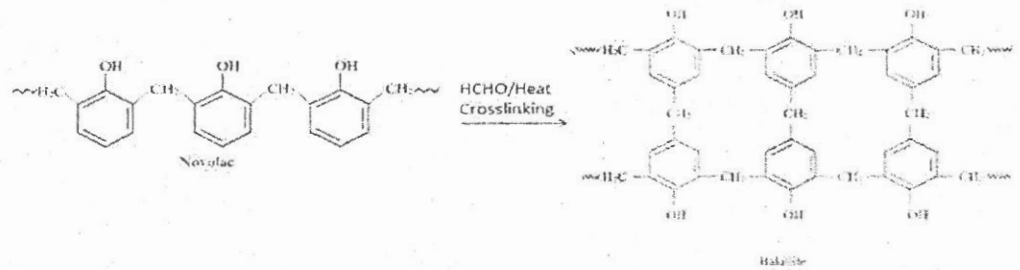

methylolphenols.

Step-II

When methylol phenols are heated with excess of phenol in presence of acid catalyst,the methylol phenols condense with phenol through methylene linkages to **from linear product novolac** with the elimination of water molecule.




**Step-III** Furtherheatingnovolacandphenolinthepresenceofacatalyst(hexamethylenetetramine)leads to formation of hard,rigid,infusible



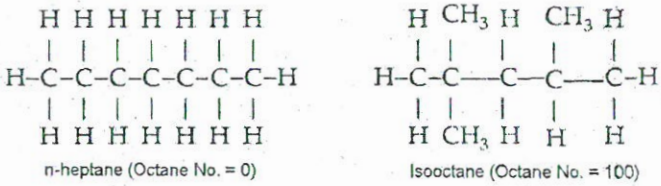

cross linked polymer called bakelite.

**7(b). Explain Octane number and Cetane Number its Significance. (5 Marks)**

**Answer: Octane number** (*Octane rating*): It has been found that n-heptane knocks very badly and hence, itsanti-knock value is arbitrarily given zero. On the other hand, isooctane (2,2,4-trimethyl pentane)gives very little knocking and so its anti-knock value has been given as 100. Thus, *octane number*

*of*

*agasolineoranyotherfuelofinternalcombustionengineisthepercentageofisooctaneinamixtureof isooctane and n-heptane, which has the same knocking characteristics as the fuel.* Greater theoctanenumber,greateristhe resistancetoknocking.

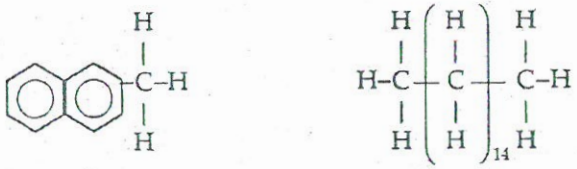



**Improvementofanti-knockingcharacteristics:**Anti-knockingcharacteristicsofafuelcanbeimprovedinthreeways:

- By the addition of suitable additives like tetraethyl lead (TEL), diethyl telluride, etc. When asmall quantity of TEL (0.5 mL per litre of petrol) is added to petrol, it decomposes thermallyto form ethyl free radicals which combine with the growing free radicals during knockingprocessandthus,terminatesthechainsoffreeradicals.Hence,knockingwillcease.Howeve r, combustion of leaded petrol forms litharge (PbO), which deposits on inner walls ofcylinderandjamspiston.
- Petrol with low octane number is blended with high octane compounds like isopentane,isooctane,ethyl benzene, methyl tertiarybutyl ether,etc.
- Structural modification of compounds in gasoline by 'reforming' also improves the anti-knockingproperty.Reforminginvolvesdehydrogenation,hydrocracking,isomerisation,etc.

**Cetane number:** In a diesel engine, the fuel is ignited by the application of heat and pressure and notby an electric spark. After the fuel enters the cylinder, it gets vapourized. These vapours combinewith heated air in the cylinder leading to rise of temperature and pressure in the cylinder. It causesignition of fuel.i.e., combustion of afuelin adieselengine is not instantaneous.The intervalbetween the fuel injection and its ignition is called ignition delay. It is an important quality of dieselfuel. Long ignition delays lead to accumulation of more vapours in the engine and when ignited, anexplosion results as the combined effect of increased temperature and pressure. This is responsiblefor knocking in diesel engines. The ignition quality of diesel fuel is expressed in terms of cetane number.

Cetane (n-hexadecane), a straight chain saturated hydrocarbon having a very short ignitiondelay is given the cetane number as 100 in the rating scale. 2-methyl naphthalene having a longerignition delay is given cetane number as 0. Thus, *cetane number of a diesel fuel is the percentage ofcetane in a mixture of cetane and 2-methyl naphthalene, which has the same ignition delay as thefuel.* Greater the cetane number, lower the ignition delay and greater the resistance to knocking indieselengines.




**Cetanenumberisfoundtodecreaseinthefollowingorder:**

***Straight-chainparaffins > Cycloparaffins > Olefins > Branched-chainparaffins > Aromatics***

Straing-chain alkanes like cetane have low ignition delay (high ignition quality) and aromatics havehigh ignition delay. This order indicates that hydrocarbons which are poor gasoline fuels can act asquite good diesel fuels. Cetane number of a diesel fuel can be improved by adding pre-ignition dopeslikeethyl nitrateandisoamyl nitrate.

**UNIT – IV (5 Marks Each)**

**8(a). Define Composites. Mention the Properties and Engineering Applications of Fibre Reinforced Composites (FRC). (5 Marks)**

Answer:

**Definition:**

A composite is a material made by combining two or more different materials to obtain better properties than the individual materials. Fibre Reinforced Composites (FRC) consist of fibres embedded in a matrix.

**Properties:**

High strength and low weight.

Good corrosion resistance.

**High stiffness.**

Excellent durability.

Good thermal and electrical insulation.

Engineering Applications:

Aircraft and spacecraft parts.

Automobile body parts.

Bridges and buildings.

Sports equipment.

Boat and ship construction.

Conclusion:

FRCs are widely used because they are strong, lightweight, and durable.

**8(b). Distinguish between Flash Point and Fire Point of Lubricants. (5 Marks)**

**Answer:**

A detailed breakdown of the differences includes:

| | Flash Point | Fire Point |
|---|---|---|
| **Definition** | Lowest temperature where vapors flash/ignite briefly. | Lowest temperature where vapors sustain continuous combustion. |
| **Burning Duration** | Momentary (flash disappears). | Continuous for at least 5 seconds. |
| **Temperature** | Lower temperature. | Higher temperature (usually \(10^{\circ }C\) to \(30^{\circ }C\) hotter). |
| **Safety Indication** | Indicates the lowest temperature at which a brief spark can cause a localized, non-sustaining fire hazard. | Indicates the temperature at which a full-scale, sustaining fire will occur if exposed to an ignition source. |
| **Testing Apparatus** | Commonly measured using **Pensky-Martens** or **Cleveland Open Cup** testers. | Measured using the same testers by continuing to heat the oil. |

**9(a). Discuss the Mechanism of Setting and Hardening of Portland Cement. (5 Marks)**

**Answer:** Setting & Hardening of Cement

The term 'Setting' is used to describe the stiffening of the cement paste. Setting of cement refers to changes of cement paste from a fluid to rigid state. The term 'Hardening' refers to the gain of strength of a set cement paste, although during setting the cement paste acquires some strength.

$3\ CaO.Al_2O_3 + 6\ H_2O \longrightarrow 3\ CaO.Al_2O_3.6\ H_2O + 880\ KJ/Kg$

$C_3A + 6\ H_2O \longrightarrow C_3A.\ 6\ H_2O + 880\ KJ/Kg$

tricalcium aluminate — hydrated tricalcium aluminate (crystalline)

$4\ CaO.Al_2O_3.Fe_2O_3 + 7\ H_2O \longrightarrow 3\ CaO.Al_2O_3.6\ H_2O + Cao.Fe_2O_3.H_2O + 420\ KJ/Kg$

$C_4AF + 7\ H_2O \longrightarrow C_3A.\ 6\ H_2O + CF.H_2O + 420\ KJ/Kg$

tetracalcium alumino ferrite — (crystalline) gel

**Reactions involved in setting and hardening of cement:-** When cement is mixed with water, the paste becomes rigid within a short time which is known as initial setting. This is due to the hydration of tricalcium aluminates and gel formation of tetra calcium alumina ferrite.

$2(2\ CaO.SiO_2) + 4\ H_2O \longrightarrow 3\ CaO.2SiO_2.6H_2O + Ca(OH)_2 + 250KJ/Kg$

$2\ C_2S + 4\ H_2O \longrightarrow C_3S_2.6H_2O + Ca(OH)_2 + 250\ KJ/Kg$

**9(b). Mention the properties applications and factors affeccting refractory materials(5 Marks)**

propertiesofrefractories.

- Refractoriness.
- RUL.[RefractorinessUnder Load]
- Porosity.
- Thermal spalling.
- Dimensionalstability.
- Thermalconductivity.

Applications of refractories

- Refractory materials are used to make furnaces, kilns, incinerators, and reactors.
- To make crucibles
- Moulds for casting glass and metals
- Surfacing flame deflector systems for rocket launch structures.
- Used to make different parts of solid and liquid rockets, nuclear propulsion devices and high performance air breathing devices such as ramjet engines
- Valves for missiles

## UNIT – V (5 Marks Each)

**10(a). Define Colloids. Mention the Applications of Colloids in Catalysis, Medicine and Soaps. (5 Marks)**

**Answer:**

A colloid is a heterogeneous mixture where microscopically small, insoluble particles of one substance are suspended throughout another substance. These suspended particles range from 1 to 1000 nanometers in size—large enough to remain permanently suspended without settling, but small enough to be invisible to the naked eye. Colloidal systems are integral to numerous industrial and biological processes. Specific applications include:

**1. Catalysis**

- **Large Surface Area:** Colloidal particles possess an enormous surface area per unit mass, making them highly effective as catalysts.
- **Heterogeneous Catalysis:** Many industrial catalysts are prepared in colloidal states.
- **Examples:** finely divided colloidal metals like platinum, nickel, and iron are widely used in hydrogenation, ammonia synthesis (Haber process), and other vital chemical reactions.

**2. Medicine**

- **Targeted Drug Delivery:** Colloidal carriers (e.g., liposomes and nanoparticles) allow therapeutic medicines to be easily absorbed and delivered directly to targeted areas within the body. [1]
- **Diagnostics and Antimicrobials:** Colloidal gold is used in diagnostics, while silver sols (like Argyrol) act as effective germicides and eye lotions.
- **Plasma Expanders:** Intravenous colloidal fluids (e.g., dextran) are used to maintain blood volume during surgery or shock.
- **3. Soaps and Detergents**
- **Micelle Formation:** Soaps and detergents function by forming colloidal structures known as micelles when dissolved in water above a certain concentration. [1]
- **Emulsification:** The hydrocarbon chains of the soap molecules attach to oils and grease, while the ionic heads interact with the water. This allows grease and dirt to be emulsified, trapped, and easily washed away.

**10(b). Explain the Green Synthesis of Gold Nanoparticles using Neem Leaf Extract. (5 Marks)**

Answer:Definition:

Green synthesis is an eco-friendly method for preparing gold nanoparticles using plant extracts instead of harmful chemicals.

**Procedure:**

Prepare fresh neem leaf extract.

Add the extract to a gold chloride ($HAuCl_4$) solution.

The biomolecules present in neem reduce gold ions ($Au^{3+}$) to gold nanoparticles ($Au^0$).

The solution changes from yellow to ruby red, indicating the formation of gold nanoparticles.

**Advantages:**

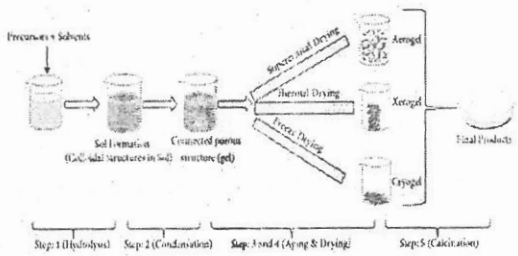
Eco-friendly.Low cost.Non-toxic.Simple and safe method.

**Applications:**

Drug delivery. Medical diagnosis. Catalysis. Biosensors.

**11(a). Explain the Sol–Gel Method for the Synthesis of Nanomaterials. (5 Marks)**

Answer:




The **sol-gel method** is a wet-chemical, "bottom-up" technique used to synthesize nanomaterials, thin films, and ceramics. It involves transforming a liquid colloidal suspension (sol) into a solid, 3D network (gel) through controlled hydrolysis and condensation reactions.

**The Sol-Gel Process: Step-by-Step**

The sol-gel method typically involves the following sequential stages:

1. **Sol Preparation:** Metal alkoxides or metal salts (precursors) are dissolved in a solvent (water or alcohol).
2. **Hydrolysis:** Water reacts with the metal precursors, replacing the alkoxide groups with reactive hydroxyl (-OH) groups.
3. **Condensation:** Hydroxylated molecules link together, forming a metal-oxygen-metal (-M-O-M-) network and releasing byproducts like water or alcohol.

4. **Gelation:** As condensation continues, the particles link into a continuous 3D network. The liquid "sol" dramatically increases in viscosity, setting into a rigid jelly-like mass known as a "gel".
5. **Aging:** The gel is left to sit in its solvent for hours or days. This strengthens the network through continued condensation, preventing shrinkage and cracking during drying.
6. **Drying:** The trapped solvent is removed.
   - *Xerogels* are dried at ambient conditions (shrinking significantly).
   - *Aerogels* are dried supercritically to maintain extreme porosity and low density.
7. **Calcination (Optional):** The dried gel is heated (often to 400°C - 600°C) to burn off residual organics and crystallize the final ceramic or metal oxide.

**11(b). Explain Freundlich Adsorption Isotherm and Langmuir Adsorption Isotherm. (5 Marks)**

**Answer:** Adsorption isotherm (Freundlich and Longmuir) Types of Adsorption Isotherms:

- The extent of adsorption of a gas per unit mass of the adsorbent depends up on the pressure of the gas. 24
- A plot of the amount of adsorption per unit mass of the adsorbent and gas pressure keeping the temperature constant is called the adsorption isotherm.

The various types of adsorption isotherm are as follows.

- **Freundlich Adsorption Isotherm:**

In 1909 Freundlich proposed an empirical equation for expressing the variation of adsorption of a gas with pressure at constant temperature.

"The amount of gas adsorbed by unit mass of the adsorbent (x/m: where x = amount of gas adsorbed, m = mass of adsorbent) is related to the adsorption equilibrium pressure (P) of the gas, at any temperature".

The mathematical relation is known as Freundlich adsorption isotherm.

$\frac{x}{m} = K.P^{1/n}$ ..... (1)

Where x = amount of adsorbate gas

m= mass of adsorbent,p= adsorption equilibrium pressure

- At low pressure, the graph is a straight line,

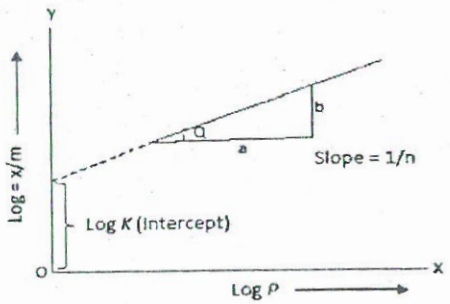
  x/m = KP, where k is constant

- At high pressure, the graph becomes almost parallel to X-axis, it indicates x/m = constant
- $\frac{x}{m} = K.P^{1/n}$ At intermediate pressure, x/m will depends on fractional power of pressure. i.e.

Where n is the whole number, its value depends on the nature of adsorbate and adsorbent. On taking log of both sides equation (1) becomes

$$log\frac{x}{m} = logK + 1/nlogP$$

The plot of log x/m vs log P should be a straight line with slope 1/n and intercept log k.




**Limitations of Freundlich adsorption isotherm:**

- It fails when pressure is high and when the concentration of adsorbent is very high. It is valid only within a limited range of pressure.
- The constant k and n change with temperature.

- It has no theoretical foundation; it is only an empirical formula.

**Langmuir adsorption isotherm:**

In 1916, Irving Langmuir proposed another adsorption isotherm which explained the variation of adsorption with pressure.

Based on his theory, he derived Langmuir Equation which depicted a relationship between the number of active sites of the surface undergoing adsorption and pressure.

**Assumptions of Langmuir isotherm:**

- Fixed number of vacant or adsorption sites are2a5vailable on the surface of solid.
- All the vacant sites are of equal size and shape on the surface of adsorbent.
- Each site can hold maximum of one gaseous molecule and a constant amount of heat energy is released during this process.
- Dynamic equilibrium exists between adsorbed gaseous molecules and the free gaseous molecules.

$$A(g) + B(S) \underset{\text{desorption}}{\overset{\text{Adsorption}}{\rightleftharpoons}} AB$$

Where A (g) is unadsorbed gaseous molecule, B(s) is unoccupied metal surface and AB is adsorbed gaseous molecule.

- Adsorption is monolayer or unilayer.

**Derivation:**

Langmuir equation which depicts a relationship between the number of active sites of the surface undergoing adsorption (i.e. extent of adsorption) and pressure.

Let θ the number of sites of the surface which are covered with gaseous molecules. Therefore, the fraction of surface which are unoccupied by gaseous molecules will be $(1 - \theta)$.

Now, Rate of forward direction depends upon two factors: Number of sited available on the surface of adsorbent, $(1 - \theta)$ and Pressure, P. Therefore, rate of forward reaction is directly proportional to both mentioned factors.

Rate of forward reaction $\propto P(1 - \theta)$ Rate of adsorption $\propto P(1 - \theta)$

Or, Rate of adsorption = $Ka\ P(1 - \theta)$

Similarly, Rate of backward reaction or Rate of Desorption depends upon number of sites occupied by the gaseous molecules on the surface of adsorbent.

Rate of desorption $\propto \theta$

Or, Rate of desorption = $Kd\ \theta$

At equilibrium, rate of adsorption is equal to rate of desorption.

$Ka\ P(1 - \theta) = Kd\ \theta$

We can solve the above equation to write it in terms of θ.

$Ka\ P - Ka\ P\ \theta = Kd\ \theta$

$Ka\ P = Ka\ P\ \theta + Kd\ \theta$

$\theta\ Ka\ P\ Kd + Ka\ P$

Divide numerator and denominator on RHS by Kd, we get

$$\theta = \frac{\frac{K_a}{K_d} P}{\frac{K_d}{K_d} + \frac{K_a}{K_d} P}$$

Now put, $K = \frac{Ka}{Kd}$

in above equation,

$\theta = K\ P$

$1+K\,P$

This is known as Langmuir Adsorption Equation.

At very low pressure, $K P_a << 1$ then $\theta = K P_a$ (or) $\theta \propto P_a$

This equation shows linear variation between extent of adsorption of gas and pressure. At high pressure,

$K P_a >> 1$ then $\theta = K P_a / K P_a = 1 = (Pa)^0$

i.e. zero power of pressure = it is independ2e6nt of pressure

Limitations of Langmuir adsorption Isotherm:

- This theory hold good only at low pressure.
- At high pressure, it is found that multi layers of the gases are found.
- Surface of the solids are heterogeneous, hence may have different affinities for the gas molecules.
- According to this theory, the saturation value of adsorption should be independent of temperature. But experiments show that saturation value decreases with rise of temperature.