Surface Chemistry

Recap Notes

- **Surface chemistry :** It deals with phenomena that occur at the surfaces or interfaces.
- **Adsorption :** It is the process of accumulation of molecular species at the surface rather than in the bulk of a solid or liquid.
- **Adsorbate :** The molecular species or substance, which concentrates or accumulates at the surface.
- **Adsorbent :** The material on the surface of which the adsorption takes place.

Distinction between adsorption and absorption

Adsorption	Absorption
It is a surface phenomenon, *i.e.*, it occurs only at the surface of the adsorbent.	It is a bulk phenomenon, *i.e.*, occurs throughout the body of the material.
In this phenomenon, the concentration on the surface of adsorbent is different from that in the bulk.	In this phenomenon, the concentration is same throughout the material.
Its rate is high in the beginning and then decreases till equilibrium is attained.	Its rate remains same throughout the process.

- **Desorption :** The process of removing an adsorbed substance from the surface.
- **Sorption :** The term used when both absorption and adsorption occur simultaneously.
- ΔG, ΔH and ΔS all are – ve for adsorption.
- **Types of adsorption :** Depending on forces which hold the adsorbate on the surface of adsorbent, adsorption is divided into two classes :
  - **Physical adsorption :** When the particles are held to the surface by the physical forces like van der Waals' forces, the adsorption is called *physical adsorption* or *physisorption*.
  - **Chemical adsorption :** When the particles are held to the surface by the chemical forces or by chemical bonds, the adsorption is called *chemical adsorption* or *chemisorption*.
- **Differences between physisorption and chemisorption**

Property	Physisorption	Chemisorption
Enthalpy	Low enthalpy, is of the order of 20-40 kJ mol^{-1}	High enthalpy, is of the order of 80-240 kJ mol^{-1}
Reversibility	Reversible process	Irreversible process

Effect of temperature	With the increase in temperature, extent of adsorption decreases because adsorption is an exothermic process and kinetic energy of gas molecules increases with temperature.	Chemisorption first increases with temperature upto a certain extent and then decreases. A gas adsorbed at low temperature by physical adsorption may change into chemisorption at high temperature.
Selectivity	Not selective in nature. Does not depend upon the chemical properties of adsorbent.	Highly selective in nature.
Nature and state of adsorbate	The extent of adsorption depends upon the ease of liquefaction of the gas.	The state of adsorbed molecules may be different from that in the bulk.
Activation energy	No appreciable energy needed	High activation energy needed
Pressure	Increase in pressure increases adsorption	Increase in pressure decreases adsorption
Layers	Multimolecular layer	Mono-molecular layer

- **Factors affecting adsorption of gases on solids :**
  - **Nature of adsorbent :** Greater the strained forces on the surface, more is the ease with which adsorption takes place on the surface. The activated adsorbents have high adsorbing power.
  - **Surface area of adsorbent :** Greater the surface area, more is the adsorption.
  - **Nature of gas being adsorbed :** Easily liquefiable gases like NH_3, HCl, Cl_2, SO_2, CO_2, etc. (whose critical temperature is high) are adsorbed to greater extent.
  - **Pressure :** At constant temperature, adsorption increases with increase in pressure. The effect of pressure is large at low temperature.
  - **Temperature :** Since adsorption is an exothermic process so according to Le-Chatelier's principle adsorption decreases with increase in temperature.
- **Freundlich adsorption isotherm :**

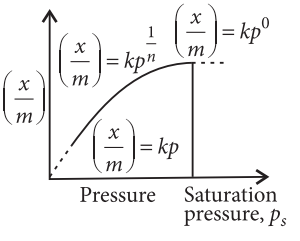
The plot of $\frac{x}{m}$ *vs* pressure at constant temperature is called *Freundlich adsorption isotherm*,

where, m = mass of the adsorbent, x = mass of the adsorbate

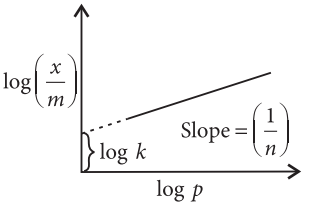
For low pressure, $\frac{x}{m} \propto p$

For high pressure, $\frac{x}{m} \propto p^0$

For intermediate pressures, $\frac{x}{m} \propto p^{1/n}\ (n > 1)$

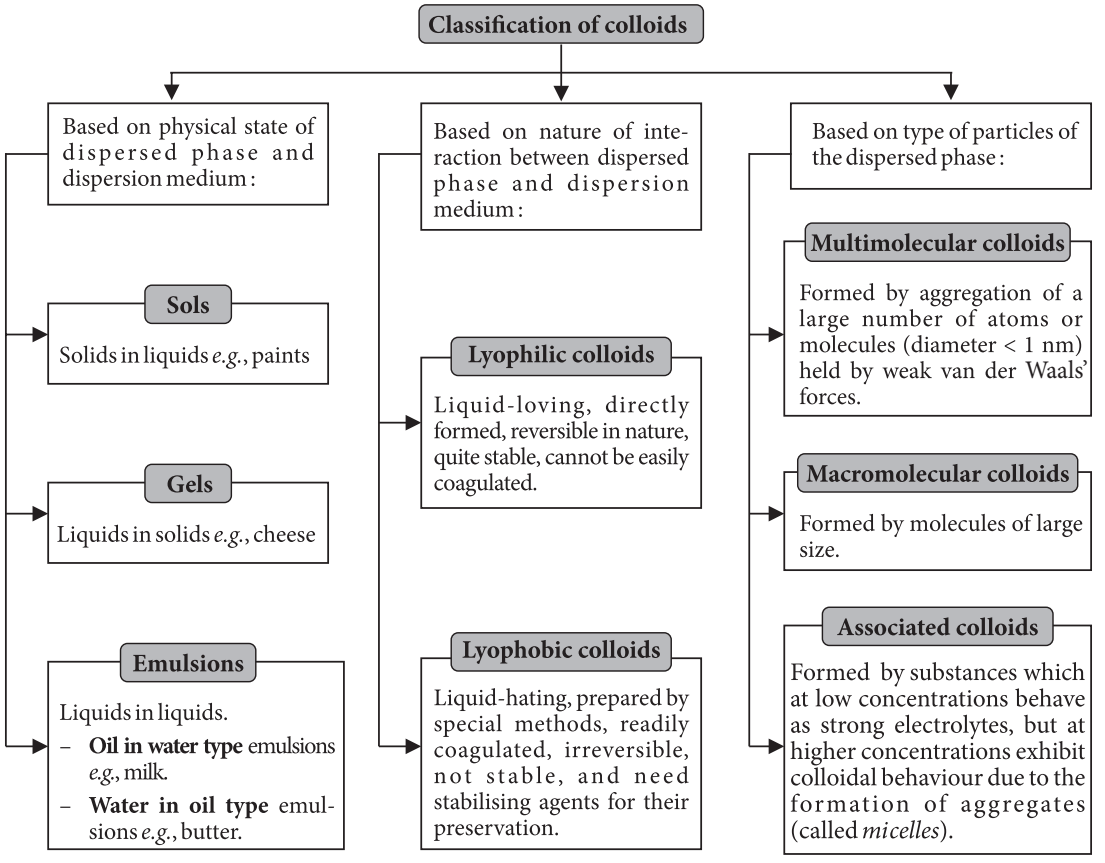


$$\log \frac{x}{m} = \log k + \frac{1}{n} \log p$$



Similarly, for adsorption of solutes from solutions, $\frac{x}{m} = k.C^{1/n}$ where, C is the equilibrium concentration, *i.e.*, when adsorption is complete.

Plot of $\log \frac{x}{m}$ *vs* log C is linear.



- **Properties of colloidal solutions :**
  - **Colligative properties :** Colloids show colligative properties like relative lowering of vapour pressure, elevation of boiling point, etc. and magnitude of colligative properties of colloids is much less than true solutions due to larger size of colloidal particles.
  - **Tyndall effect (Optical property) :** Scattering of light by colloidal particles due to which the path of light beam becomes visible.
  - **Brownian movement (Mechanical property):** Zig-zag movement of colloidal particles due to the unbalanced bombardment by the molecules of dispersion medium.
  - **Charge on colloidal particles :** Colloidal particles always carry an electric charge and nature of charge (+ve or –ve) is same on all the particles in a given colloidal solution. The charge is due to preferential adsorption of ions from solution.

Positively charged sols	Negatively charged sols
Hydrated metallic oxides, *e.g.*, $Al_2O_3 \cdot xH_2O$, $Fe_2O_3 \cdot xH_2O$, metal hydroxides, *e.g.*, $Fe(OH)_3$, $Al(OH)_3$, basic dye stuff like Prussian blue, haemoglobin (blood), etc.	Metallic particles, *e.g.*, Cu, Ag, Au Metal sulphides, *e.g.*, As_2S_3, CdS, Acidic dyes like eosin, congo red etc, sols of gelatin, gum, starch, etc.

  - **Electrophoresis (Electrical property):** Movement of colloidal particles towards one of the electrodes on passage of electricity through colloidal solution. The direction depends on the type of charge on colloidal particles.
  - **Coagulation of colloids :** Precipitation of colloidal solution by induced aggregation of colloidal particles.
    - **Lyophobic sols:** They can be coagulated by electrophoresis, boiling, persistent dialysis, mixing of oppositely charged sols and addition of electrolytes.

– **Hardy–Schulze rules :**

- In case of electrolytes, the ion carrying charge opposite to that of colloidal particles is effective in causing coagulation and greater the valency of the ion causing coagulation, greater is the coagulating power.
- The minimum concentration of an electrolyte in millimoles per litre required to cause precipitation of a sol in two hours is called *coagulating value*. The smaller the quantity needed, the higher will be the coagulating power of an ion.

– **Lyophilic sols :** They can be coagulated by addition of electrolytes or addition of a suitable solvent.

Practice Time

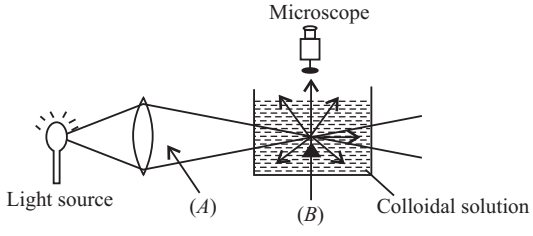
OBJECTIVE TYPE QUESTIONS

Multiple Choice Questions (MCQs)

1. Which of the following statements is not correct about physiosorption?
(a) It is a reversible process.
(b) It requires less heat of adsorption.
(c) It requires activation energy.
(d) It takes place at low temperature.

2. The term activation of adsorbent is used when
(a) adsorbing power is increased by increasing surface area by making the surface rough
(b) adsorbing power is increased by dipping the surface in acid to make it smooth
(c) adsorbing power is increased by dissolving it in water
(d) adsorbing power is decreased to reduce the extent of adsorption.

3. When a colloidal solution is viewed from the direction at right angles of light beam, the path of the beam is illuminated due to scattering of light. In the figure (*A*) and (*B*) are



(a) *A* - Tyndall cone, *B* - Scattered light
(b) *A* - Scattered light, *B* - Tyndall cone
(c) *A* - Tyndall cone, *B* - Blind spot
(d) *A* - Tyndall effect, *B* - Tyndall cone

4. Which of the following statements does not show correct difference between adsorption and absorption?
(a) In adsorption the substance is concentrated only at the surface while in absorption it is uniformly distributed in the bulk.
(b) Adsorption is instantaneous while absorption is a slow process.
(c) A substance can be adsorbed as well as absorbed simultaneously and the process is called sorption.
(d) Only gases are adsorbed while solids and liquids are absorbed.

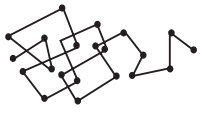
5. Which of the following is not a method for coagulation of lyophobic sols?
(a) By electrophoresis
(b) By mixing oppositely charged sols
(c) By adding electrolyte
(d) By adding a protective colloid

6. Mixing of positively charged colloidal solution with negatively charged colloidal solution brings _____. The decreasing order of coagulating power of Na^+, Ba^{2+} and Al^{3+} for negatively charged colloidal solution is _____.
(a) mutual coagulation, $Na^+ > Ba^{2+} > Al^{3+}$
(b) mutual coagulation, $Al^{3+} > Ba^{2+} > Na^+$
(c) coagulation, $Na^+ > Ba^{2+} > Al^{3+}$
(d) peptization, $Al^{3+} > Ba^{2+} > Na^+$

7. Movement of dispersion medium under the influence of electric field is known as
(a) electrodialysis (b) electrophoresis
(c) electroosmosis (d) cataphoresis.

8. Why is alum added to water containing suspended impurities?
(a) To make a colloidal solution.
(b) To coagulate the suspended impurities.
(c) To remove impurities of calcium and magnesium.
(d) To protect the colloidal solution from getting precipitated.

9. The cause of Brownian movement which is not shown by true solutions or suspensions is due to



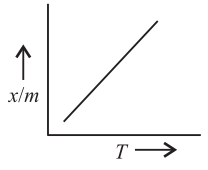
(a) unbalanced bombardment of particles by molecules of the dispersion medium

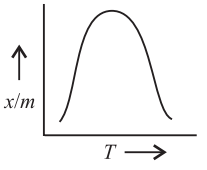
(b) attractive forces between dispersed phase and dispersion medium
(c) larger size of the particles due to which they keep colliding and settling down
(d) conversion currents formed in the sol.

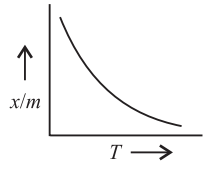
10. Which of the following is less than zero during adsorption?
(a) ΔG (b) ΔS
(c) ΔH (d) All of these.

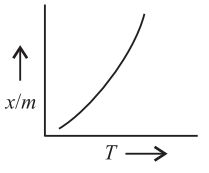
11. Substances which behave as normal electrolytes in solution at low concentration and exhibit colloidal properties at higher concentration are called
(a) lyophilic colloids
(b) lyophobic colloids
(c) macromolecular colloids
(d) associated colloids.

12. Which of the plots is adsorption isobar for chemisorption?

(a) 

(b) 

(c) 

(d) 

13. A colloidal system in which liquid is dispersed phase and solid is dispersion medium is classified as
(a) gel (b) sol
(c) emulsion (d) aerosol.

14. Which of the following gases is least adsorbed on charcoal?
(a) HCl (b) NH_3
(c) O_2 (d) CO_2

15. What is the role of activated charcoal in gas masks used in mines?
(a) It acts as an adsorbent for poisonous gases present in coal mines.
(b) It acts as an adsorbent for coal particles present in coal mines.
(c) It acts as a mask through which exhaled gases are diffused out.
(d) It acts as a base for scattering the light.

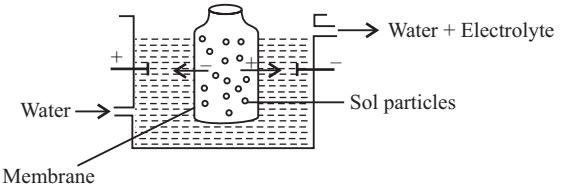
16. Which of the following statements is not correct for chemisorption and physisorption?
(a) Physisorption and chemisorption are both exothermic processes.
(b) Magnitude of chemisorption is favourable at low temperature while physisorption is favourable at high temperature.
(c) Chemisorption is irreversible and physisorption is reversible.
(d) In physisorption activation energy is low while in chemisorption it is high.

17. The combination of two layers of opposite charges around the colloidal particles is called Helmholtz electrical double layer. The potential difference between the fixed layer and the diffused layer of opposite charges is called
(a) electrode potential (b) zeta potential
(c) adsorption potential (d) diffused potential.

18. A lyophobic colloid cannot be formed by
(a) mixing dispersed phase and dispersion medium
(b) chemical reactions like hydrolysis
(c) exchange of solvent
(d) peptisation.

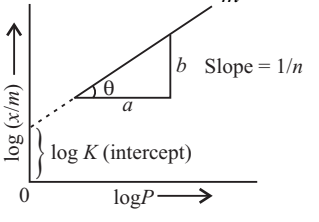
19. The substances which behave as normal electrolytes at low concentration but undergo association at higher concentration and behave as colloidal solutions are called
(a) associated colloids
(b) multimolecular colloids
(c) macromolecular colloids
(d) protective colloids.

20. Which of the processes is being shown in the figure?



(a) Electrodialysis (b) Dialysis
(c) Electroosmosis (d) Electrophoresis

21. A graph is plotted between log (x/m) and log P according to the equation $\frac{x}{m} = kP^{1/n}$



Which of the following statements about this graph is not correct?

(a) The figure shows Freundlich adsorption isotherm.
(b) The figure shows Langmuir adsorption isotherm.
(c) The adsorption varies directly with pressure.
(d) The factor $1/n$ can have values between 0 and 1.

22. Lyophilic sols are also called reversible colloids because
(a) they can be reformed by mixing residue (dispersed phase) in dispersion medium even after drying
(b) they can be easily precipitated from the colloidal system
(c) once formed, the dispersion medium and dispersed phase cannot be separated
(d) special reversible reactions are used to prepare them.

23. Which of the following gases present in a polluted area will be adsorbed most easily on the charcoal gas mask?
(a) H_2 (b) O_3
(c) N_2 (d) SO_2

24. $Fe(OH)_3$ sol can be more easily coagulated by Na_3PO_4 in comparison to KCl because
(a) mass of Na_3PO_4 is more than KCl hence it is more effective than KCl
(b) phosphate ion (PO_4^{3-}) has higher negative charge than Cl^- ion hence are more effective for coagulation
(c) KCl is more soluble than Na_3PO_4 hence less effective for coagulation
(d) Na^+ ions are more effective than K^+ ions for coagulation.

25. Colloidal solutions of metals like gold can be prepared when their salt solutions react with certain substances like $SnCl_2$, formaldehyde, phenyl hydrazine, etc.

$$2AuCl_3 + 3SnCl_2 \rightarrow \underset{\text{sol}}{3SnCl_4 + 2Au}$$

The above method is an example of
(a) reduction method
(b) oxidation method
(c) hydrolysis method
(d) double decomposition method.

26. What is the role of adsorption in froth floatation process used especially for concentration of sulphide ores?
(a) Shape selective catalysts.
(b) Adsorption of pine oil on sulphide ore particles.
(c) Adsorption of pine oil on impurities.
(d) Production of heat in the process of exothermic reaction.

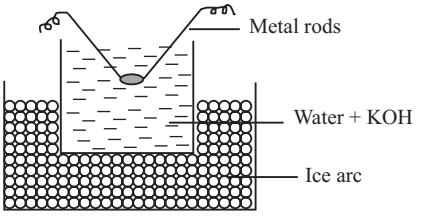
27. When an excess of a very dilute aqueous solution of KI is added to a very dilute aqueous solution of silver nitrate, the colloidal particles of silver iodide are associated with which of the following Helmholtz double layer?
(a) $AgI / Ag^+ \vdots I^-$ (b) $AgI / K^+ \vdots NO_3^-$
(c) $AgI / NO_3^- \vdots Ag^+$ (d) $AgI / I^- \vdots K^+$

28. Which of the following will not form a colloidal system?
(a) Solid-gas (b) Liquid-gas
(c) Gas-gas (d) Gas-liquid

29. Which of the following factors contribute towards higher stability of lyophilic colloid?
(a) Charge on their particles.
(b) Attractive forces between particles.
(c) Small size of their particles.
(d) High solvation due to a layer of dispersion medium.

30. Which of the following examples is correctly matched?
(a) Butter – gel (b) Smoke – emulsion
(c) Paint – foam (d) Milk – aerosol

31. In Bredig's arc method an electric arc is struck between the metal electrodes under the surface of water containing some stabilizing agent. The process involves



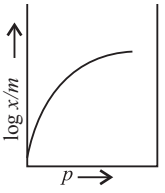
(a) mechanical dispersion
(b) condensation
(c) both dispersion and condensation
(d) ultrasonic dispersion.

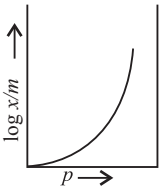
32. Fog is an example of colloidal system of
(a) liquid in gas (b) gas in liquid
(c) solid in gas (d) gas in solid.

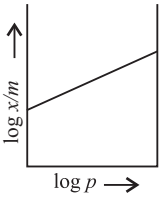
33. In these colloids, a large number of small atoms or smaller molecules of a substance aggregate to form colloidal particles having size in colloidal range. These colloids are known as

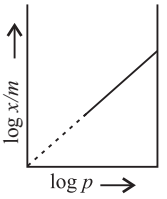
(a) multimolecular colloids
(b) macromolecular colloids
(c) associated colloids (d) lyophilic colloids.

34. Which of the following curves is in accordance with Freundlich adsorption isotherm?

(a) 

(b) 

(c) 

(d) 

35. Which of the following acts as the best coagulating agent for ferric hydroxide sol?
(a) Potassium ferrocyanide
(b) Potassium chloride
(c) Potassium oxalate (d) Aluminium chloride

36. Which of the following is not characteristic of chemisorption?
(a) Adsorption is specific.
(b) Heat of adsorption is of the order of 200 kJ mol^{-1}.
(c) Adsorption is irreversible.
(d) Adsorption may be multimolecular layers.

37. Why is ferric hydroxide colloid positively charged when prepared by adding ferric chloride to hot water?
(a) Due to precipitation of ferric hydroxide there is an excess of Fe^{3+} ions.
(b) Due to preferential adsorption of Fe^{3+} ions by the sol of $Fe(OH)_3$.
(c) Due to absence of any negatively charged ion.
(d) Due to adsorption of OH^- and Cl^- ions, the remaining sol has only Fe^{3+} ions.

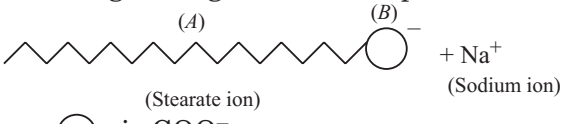
38. Which out of the following electrolyte solutions having the same concentration will be most effective in causing the coagulation of arsenic sulphide sol?
(a) KCl (b) $MgCl_2$
(c) $AlCl_3$ (d) Na_3PO_4

39. At CMC (critical micelle concentration) the surface molecules
(a) dissociate (b) associate
(c) become bigger in size due to adsorption
(d) become smaller in size due to decomposition.

40. Tyndall effect is observed only when which of the following conditions are satisfied?
(i) The diameter of the dispersed particles is not much smaller than the wavelength of the light used.
(ii) The refractive indices of dispersed phase and dispersion medium differ greatly in magnitude.
(iii) The size of the particles is generally between 10^{-11} and 10^{-9} m in diameter.
(iv) The dispersed phase and dispersion phase can be seen separately in the system.
(a) (i) and (iii) (b) (i) and (iv)
(c) (ii) and (iii) (d) (i) and (ii)

41. Which of the following is not a method of removing impurities from a colloidal sol?
(a) Electrodialysis (b) Ultrafiltration
(c) Ultra centrifugation (d) Distillation

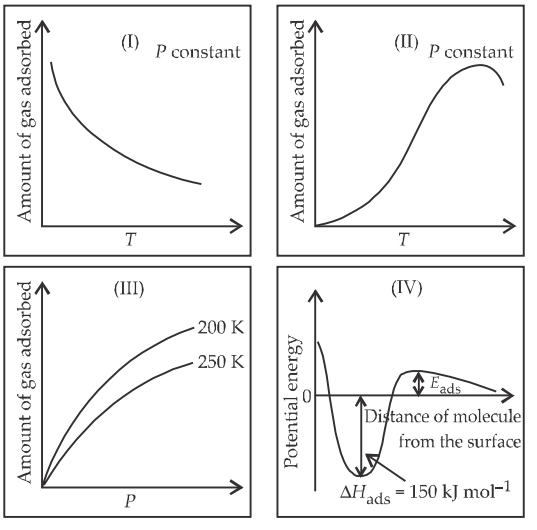
42. In the given figure label the parts.



where ◯– is COO^-

(a) *A* - Hydrophilic tail, *B* - hydrophobic head
(b) *A* - Hydrophobic tail, *B* - hydrophobic head
(c) *A* - Hydrophobic tail, *B* - hydrophilic head
(d) *A* - Hydrophilic tail, *B* - hydrophilic head

43. After reading adsorption thoroughly Shubh plotted these 4 curves :
The given graphs/data I, II, III and IV represent general trends observed for different physisorption and chemisorption processes under mild conditions of temperature and pressure. Which of the following choice(s) about I, II, III and IV is(are) correct?



Next day he showed these plots to his friend and asked about the plots and explained.

(i) Plot I represents physisorption because physisorption decrease with increase in temperature.

(ii) Plot II represents chemisorption as it initially increases upto certain extent and then decreases regularly.

(iii) Plot III represents physiosorption because it decreases with increase in both P & T.

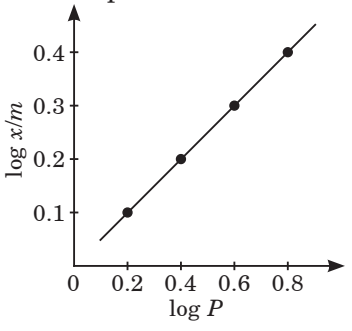
(iv) Plot IV represents chemisorption because activation energy for it is of the order 80 – 240 kJ/mol.

The incorrect observations or explanations are

(a) (i) & (iii) (b) (ii) & (iii)

(c) (i) & (iv) (d) (iii) & (iv)

44. A plot between log x/m (almost adsorbed) and log P has been plotted and it is shown below:

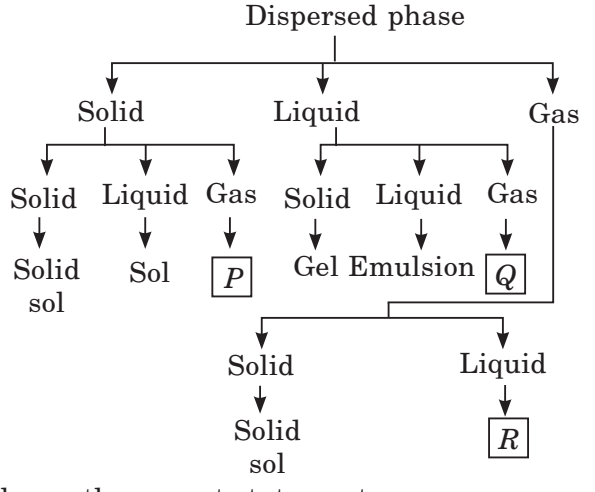


Value of n is

(a) 2 (b) 0.5

(c) 1 (d) 1.5

45. Colloids can be classified as



Choose the correct statement.

(a) Examples of P are cheese and jellies.

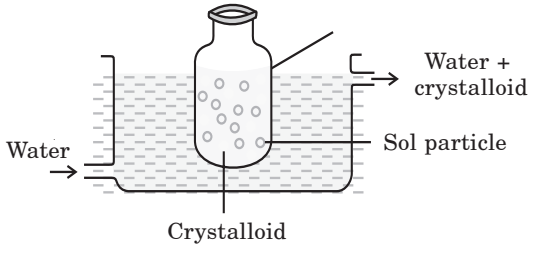
(b) Examples of Q are pumice stone and foam rubber.

(c) Examples of R are froth, whipped cream and soap lather.

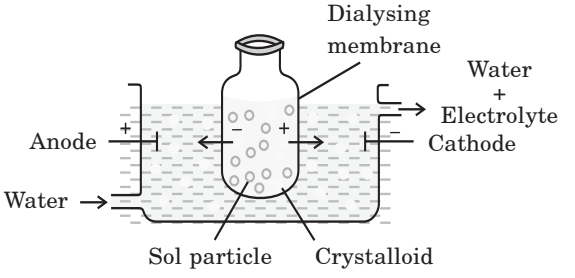
(d) P is aerosol, Q is gel and R is foam.

46. Colloidal solutions when prepared, generally contain excessive amount of electrolytes and some other soluble impurities. These soluble electrolytes if present in larger amount can coagulate the sol. So it is necessary to reduce their concentration to minimum amount.

Method I is used for purification and it can be converted to method II also.



Method I



Method II

Advantage of method II over method I is

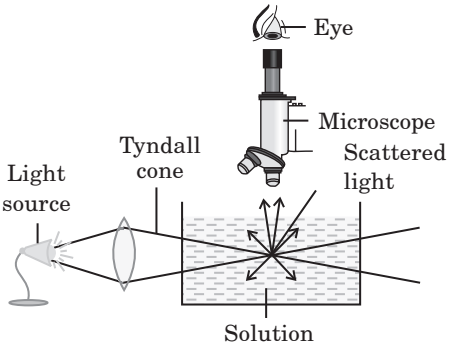
(a) it uses less energy

(b) it is cost friendly

(c) it speeds up the purification

(d) none of these.

47. Observe the given figure:



Sanjeev performed this experiment with different solutions listed here :

Sugar solution (I), salt solution (II), ink (III), milk (IV), glucose solution (V), muddy water (VI), slaked lime (VII).

Tyndall cone can not be seen in

(a) Only I, II and VII (b) I, IV and VIII

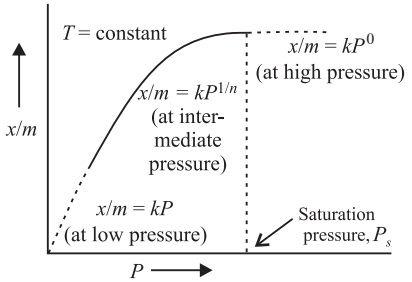
(c) II, III and IV (d) I, II and V

Case Based MCQs

Case I : Read the passage given below and answer the following questions from 48 to 52.

A graph between the amount adsorbed (x/m) by an adsorbent and the equilibrium pressure of the adsorbate at a constant temperature is called the adsorption isotherm.

A relationship between the amount adsorbed (x/m) and the equilibrium pressure (P) can be obtained as follows :



Variation of x/m with increase in pressure at constant temperature (General adsorption isotherm)

In the intermediate range of pressure, $x/m = kP^{1/n}$ (was originally put forward by Freundlich and is known as Freundlich adsorption isotherm).

48. According to Freundlich adsorption isotherm, which of the following is correct?

(a) $\frac{x}{m} \propto P^0$

(b) $\frac{x}{m} \propto P^1$

(c) $\frac{x}{m} \propto P^{1/n}$

(d) All the above are correct for different range of pressure.

49. In the Freundlich adsorption isotherm equation

$\log \frac{x}{m} = \log k + \frac{1}{n} \log p$, the value of $1/n$ is

(a) any value from 0 to 1

(b) a negative integer

(c) a positive integer

(d) a positive or a negative fractional number.

50. Plot of $\log x/m$ against $\log p$ is a straight line inclined at an angle of 45°. When the pressure is 0.5 atm and Freundlich parameter, k is 10, the amount of solute adsorbed per gram of adsorbent will be (log 5 = 0.6990)

(a) 1 g (b) 2 g

(c) 3 g (d) 5 g

51. In the plot of $\log \frac{x}{m}$ *vs* $\log p$ for an adsorption, a straight line inclined at an angle of $\theta = 14.04$ to the x-axis was obtained. The 'n' value for this adsorption process is (tan 14.04 = 0.25)

(a) 5 (b) 8

(c) 4 (d) 2

52. In the adsorption of a gas on solid, Freundlich isotherm is obeyed. The slope of the plot is zero. Then the extent of adsorption is

(a) directly proportional to the pressure of the gas

(b) inversely proportional to the pressure of the gas

(c) directly proportional to the square root of the pressure of the gas

(d) independent of the pressure of the gas.

Case II : Read the passage given below and answer the following questions from 53 to 57.

Adsorption is a spontaneous process and involves unequal distribution of the molecules of the gaseous substance on the surface of solid or liquid. Adsorption is an exothermic process. The attractive forces between adsorbate and adsorbent are either van der Waals' forces or chemical bonds. Adsorption of gases on solids is generally controlled by the factors like temperature, pressure and nature of adsorbate and adsorbent.

53. In physisorption process, the attractive forces between adsorbate and adsorbent are

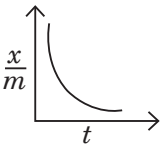
(a) covalent bonds

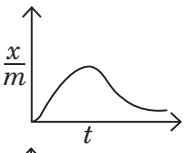
(b) ionic bonds

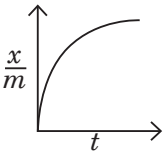
(c) van der Waals' forces

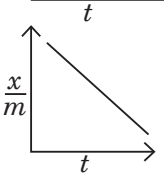
(d) H-bonds.

54. Which of the following graph represents the variation of physical adsorption with temperature?

(a) 

(b) 

(c) 

(d) 

55. Which one of the following processes does not use adsorption?
(a) Froth floatation process
(b) Chromatography
(c) Decolourisation of sugar liquors
(d) Dissolution of sugar in water

56. Which of the following statements is true?
(a) Chemisorption forms unimolecular layer.
(b) Chemisorption is a reversible process.
(c) Chemisorption is independent of pressure.
(d) Chemisorption has low enthalpy change.

57. Methylene blue, from its aqueous solution, is adsorbed on activated charcoal at 25°C. For this process, the correct statement is
(a) the adsorption requires activation at 25°C
(b) the adsorption is accompanied by a decrease in enthalpy
(c) the adsorption increases with increase of temperature
(d) the adsorption is irreversible.

Case III : Read the passage given below and answer the following questions from 58 to 62.

Hardy Schulze rule states that the precipitating effect of an ion on dispersed phase of opposite charge increases with the valency of the ion. The higher the valency of the flocculating ion, the greater is its precipitating power. Thus, for the precipitation of As_2S_3 sol (–ve sol) the precipitating power of Al^{3+}, Ba^{2+} and Na^+ ions is of the order, $Al^{3+} > Ba^{2+} > Na^+$. Similarly, for precipitating $Fe(OH)_3$ sol (+ve sol) the precipitating power of $[Fe(CN)_6]^{3-}$, SO_4^{2-} and Cl^- is of the order, $[Fe(CN)_6]^{3-} > SO_4^{2-} > Cl^-$. The minimum concentration of an electrolyte in millimoles per litre required to cause precipitation of a sol in 2 hours is called flocculation value. The smaller the flocculation value, the higher will be the coagulating power of the ion. The minimum mass of the protective colloid (lyophilic colloid) in milligrams that must be added to 10 mL of a standard red gold sol so that no coagulation occurs when 1 mL of 10% NaCl solution is rapidly added to it is called the gold number of the protective colloid.

58. The gold number of four protective colloids *A*, *B*, *C* and *D* are 0.03, 0.003, 10 and 30 respectively. Protective power of these colloids will be of the order :
(a) $B > A > C > D$ (b) $A > B > C > D$
(c) $C > B > D > A$ (d) $D > A > C > B$

59. Which of the following has least flocculating value for positive sol?
(a) Cl^- (b) SO_4^{2-}
(c) PO_4^{3-} (d) $[Fe(CN)_6]^{4-}$

60. Which of the following colloidal solutions is positively charged?
(a) TiO_2 (b) As_2S_3
(c) Starch sol (d) Gold sol

61. The coagulation value in millimoles per litre of electrolytes used for the coagulation of As_2S_3 are as below :
I. NaCl = 52
II. KCl = 50
III. $BaCl_2$ = 0.69
IV. $MgSO_4$ = 0.72
The correct order of their flocculating power is
(a) I > II > III > IV (b) I > II > IV > III
(c) I < II < IV < III (d) IV < I < II < III

62. 1 mol of AgI/Ag^+ is coagulated by
(a) 1 mol of KI
(b) 200 mL of 1 M K_2SO_4
(c) 300 mL of 1 M Na_3PO_4
(d) 2 mol of AgI

Case IV : Read the passage given below and answer the following questions from 63 to 67.

Adsorption depends on the nature of the adsorbent. The rough solid surface has more number of pores and adsorb more number of gases than the smooth surface. Most common adsorbents are silica gel, activated charcoal. The extent of adsorption also depends on the surface area of the solid. Specific surface area of an adsorbent is the surface area available for adsorption per gram of the adsorbent. The greater the surface area of the solid, the greater would be the adsorption. Charcoal is a more

effective adsorbent than solid wood. Desorption is a process of removing an adsorbed substance from a surface on which it is absorbed.

Physisorption is non-specific and any gas can be adsorbed. But the gases which are easily liquefiable (*e.g.*, NH_3, HCl, CO_2) are adsorbed at a faster rate and to a large extent than the gases which are difficult to liquefy (*e.g.*, H_2, O_2, N_2). It depends on the critical temperature. Higher the critical temperature of a gas, more easily liquefiable the gas is and more is the rate of adsorption. Chemisorption is specific in nature. Therefore, only those gases can be adsorbed which are capable of forming chemical bonds with the adsorbent.

63. Select the correct statement regarding desorption of gases on solid.

(a) It is done by cooling or by increasing the pressure applied.
(b) It is done by cooling or by reducing the pressure applied.
(c) It is done by heating or by reducing the pressure applied.
(d) It is done by heating or by increasing the pressure applied.

64. Which of the following statements regarding the physical adsorption of a gas on surface of solid is not correct?

(a) On increasing temperature, adsorption increases continuously.
(b) Enthalpy changes are negative.
(c) It is non-specific in nature.
(d) It is reversible in nature.

65. At the same temperature and pressure, select the correct order of adsorption of the following gases on the same mass of charcoal.

(a) $SO_2 > CH_4 > H_2$ (b) $CH_4 < SO_2 < H_2$
(c) $H_2 > CH_4 > SO_2$ (d) $CH_4 < H_2 < SO_2$

66. Select the correct option among the following when adsorption of a gas on solid metal surface is spontaneous and exothermic.

(a) ΔS increases. (b) ΔS decreases.
(c) ΔG increases. (d) ΔH increases.

67. Select the incorrect statement among the following.

(a) Physical adsorption is favourable at low temperature and chemisorption is favourable at high temperature.
(b) In physisorption heat of adsorption lies between 20-40 kJ mol^{-1} while in chemisorption it lies between 80-240 kJ mol^{-1}.
(c) Chemisorption is irreversible and physisorption is reversible.
(d) Magnitude of chemisorption decreases with rise in temperature while physisorption increases with rise in temperature.

Assertion & Reasoning Based MCQs

For question numbers 68-80, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(c) Assertion is correct statement but reason is wrong statement.
(d) Assertion is wrong statement but reason is correct statement.

68. Assertion : A colloidal sol of As_2S_3 is coagulated faster by 0.1 M $BaCl_2$ than by 0.1 M NaCl.
Reason : $BaCl_2$ gives double the number of Cl^- ions than NaCl.

69. Assertion : According to Freundlich, $\frac{x}{m} = k \cdot P^{1/n}$
Reason : The isotherm shows variation of the amount of gas adsorbed by the adsorbent with temperature.

70. Assertion : There is no interface between gases.
Reason : The shape and volume of gases are not definite.

71. Assertion : Soap and detergent are macromolecular colloids.
Reason : Macromolecular colloids are formed by molecules of large size.

72. Assertion : Lyophilic colloids are called reversible sols.
Reason : Lyophilic sols are liquid loving.

73. Assertion : Colloidal particles show Brownian movement.
Reason : Brownian movement arises because of the impact of the molecules of the dispersion medium with the colloidal particles.

74. Assertion : Porous or finely divided forms of adsorbents adsorb larger quantities of adsorbate.
Reason : The greater the surface area of the solid, the greater would be its adsorbing capacity.

75. Assertion : NH_3 is adsorbed more readily than O_2 on charcoal.
Reason : More easily liquefiable gases are adsorbed easily.

76. Assertion : The molecules on the surface have lesser energy than the molecules inside.
Reason : During adsorption, the surface of solid is in a state of strain.

77. Assertion : Muddy water is an example of sol.
Reason : A colloidal system in which solid is dispersed in a liquid is called sol.

78. Assertion : Gold number is a measure of protective action by a lyophilic colloid on a lyophobic colloid.
Reason : Zeta potential (or electrokinetic potential) is the potential difference between fixed charged layer and the diffused layer having opposite charge.

79. Assertion : When $FeCl_3$ is added to an excess of hot water, a positively charged sol of hydrated ferric oxide is formed.
Reason : When ferric chloride is added to NaOH solution a negatively charged sol is obtained due to adsorption of OH^- ions.

80. Assertion : A colloidal sol scatters light but a true solution does not.
Reason : The particles in a colloidal sol move slowly than in a true solution.

SUBJECTIVE TYPE QUESTIONS

Very Short Answer Type Questions (VSA)

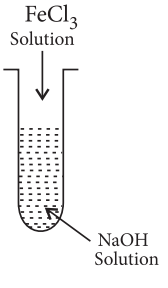
1. Explain the following :

Artificial rain is caused by spraying salt over clouds.

2. Physisorption is multi-layered, while chemisorption is mono-layered. Explain.

3. Based on the type of dispersed phase, what type of colloid is micelles?

4. A colloidal sol is prepared by the given method in figure. What is the charge on hydrated ferric oxide colloidal particles formed in the test tube? How is the sol represented?



5. Give reasons for the following observations:
A delta is formed at the meeting point of sea water and river water.

6. Out of NH_3 and CO_2, which gas will be adsorbed more readily on the surface of activated charcoal and why?

7. Name of the temperature above which the formation of micelles takes place.

8. Out of $BaCl_2$ and KCl, which one is more effective in causing coagulation of a negatively charged colloidal sol? Give reason.

9. Why are medicines more effective in colloidal state?

10. How can a colloidal solution and true solution of the same colour be distinguished from each other.

Short Answer Type Questions (SA-I)

11. Give reasons for the following observations :

(i) NH_3 gas absorbs more readily than N_2 gas on the surface of charcoal.

(ii) Powdered substances are more effective adsorbents.

12. What happens when

(a) a freshly prepared precipitate of $Fe(OH)_3$ is shaken with a small amount of $FeCl_3$ solution?

(b) persistent dialysis of a colloidal solution is carried out?

13. What is meant by coagulation of a colloidal solution? Name any method by which coagulation of lyophobic sols can be carried out.

14. (i) What is the role of activated charcoal in gas mask?

(ii) How does chemisorption vary with temperature?

15. Give reasons for the following observations:

(i) Leather gets hardened after tanning.

(ii) Lyophilic sol is more stable than lyophobic sol.

16. (i) Out of $MgCl_2$ and $AlCl_3$, which one is more effective in causing coagulation of negatively charged sol and why?

(ii) Out of sulphur sol and proteins, which one forms multimolecular colloids?

17. (i) Same substances can act both as colloids and crystalloids. Explain.

(ii) What will be the charge on AgI colloidal sol when it is prepared by adding small amount of $AgNO_3$ solution to KI solution in water? What is responsible for the development of this charge?

18. Write the differences between physisorption and chemisorption with respect to the following:

(i) Specificity (ii) Temperature dependence

(iii) Reversibility and (iv) Enthalpy change

19. Write one difference in each of the following:

(a) Multimolecular colloid and associated colloid

(b) Coagulation and peptization

20. Pressure of a closed vessel filled with gas decreases when powdered charcoal is added. Explain.

Short Answer Type Questions (SA-II)

21. Define the following terms :

(i) Lyophilic colloid

(ii) Zeta potential

(iii) Associated colloids

22. (i) Of physisorption and chemisorption, which has a higher enthalpy of adsorption?

(ii) Physisorption is reversible while chemisorption is irreversible. Why ?

(iii) What type of forces are responsible for the occurrence of physisorption?

23. Give reasons for the following :

(a) Brownian movement provides stability to the colloidal solution.

(b) True solution does not show Tyndall effect.

(c) Addition of alum purifies water.

24. Distinguish between multimolecular, macromolecular and associated colloids. Give one example of each.

25. Giving appropriate examples, explain how the two types of processes of adsorption (physisorption and chemisorption) are influenced by the prevailing temperature, the surface area of adsorbent and the activation energy of the process?

26. Explain what is observed when :

(i) A beam of light is passed through a colloidal solution.

(ii) NaCl solution is added to hydrated ferric oxide sol.

(iii) Electric current is passed through a colloidal solution.

27. (i) How are the following colloidal solutions prepared?

(a) Sulphur in water

(b) Gold sol

(ii) Why is adsorption always exothermic?

28. Classify colloids where the dispersion medium is water. State their characteristics and write an example of each of these classes.

29. Ranju is using normal water for washing clothes. She observed that her clothes were not getting very clean although she is using more amount of soaps or detergents. Her friend Swarna advised Ranju washing clothes in warm water. Ranju was surprised to see that washing of clothes with soaps or detergents is easier in luke warm water than cold water.

Now answer the following questions:

(i) What are the processes involved in washing of clothes?

(ii) Why washing of clothes using soap or detergent is easier in warm water?

30. (i) Explain the following terms giving one example for each.

(a) Micelles

(b) Aerosol

(ii) Write one similarity between physisorption and chemisorption.

31. What is meant by coagulation of a colloidal solution? Describe briefly any three methods by which coagulation of lyophobic sols can be carried out.

32. (i) Define the following terms giving an example: Hydrosol

(ii) Which complex ion is formed when undecomposed AgBr is washed with hypo solution in photography?

33. (i) What are protective colloids? Which type of colloids are used as protective colloids?

(ii) Why does sky look blue?

34. (i) Write the dispersed phase and dispersion medium of the following colloidal systems :

(a) Smoke (b) Milk

(ii) In reference to Freundlich adsorption isotherm write the expression for adsorption of gases on solids in the form of an equation.

35. (i) What is the principle of separation of inert gases from its mixture?

(ii) Why silica and alumina gels are used for removing moisture and controlling humidity?

(iii) How does adsorption of a gas on a solid surface vary with temperature?

Long Answer Type Questions (LA)

36. (a) Give reason, why a finely divided substance is more effective as an adsorbent?

(b) Physical and chemical adsorptions respond differently to rise in temperature. What is this difference and why is it so?

(c) The volume of nitrogen gas at 0°C and 1.013 bar required to cover a sample of silica gel with unimolecular layer is 129 $cm^3\ g^{-1}$ of gel. Calculate the surface area per gram of the gel if each nitrogen molecule occupies $16.2 \times 10^{-20}\ m^2$.

37. What is an adsorption isotherm? Describe Freundlich adsorption isotherm.

38. (a) Assuming adsorption to be a spontaneous process, show thermodynamically that it is always an exothermic process.

(b) Why are all adsorption processes exothermic?

(c) How is the adsorption of a gas related to its critical temperature?

(d) A small amount of silica gel and a small amount of anhydrous calcium chloride are placed separately in two corners of a vessel containing water vapour. What phenomenon will occur?

39. (i) Explain why excessive dialysis should be avoided for purification of a colloid?

(ii) What is the difference between dialysis and ultrafiltration?

40. (i) 1 g of charcoal adsorbs 100 mL of 0.5 M CH_3COOH to form a monolayer, and thereby the molarity of CH_3COOH reduces to 0.49 M. Calculate the surface area of the charcoal adsorbed by each molecule of acetic acid. Surface area of charcoal $= 3.01 \times 10^2\ m^2$.

(ii) A solution of palmitic acid (M = 256g) in benzene contains 4.24 g acid per litre. When this solution is dropped on the water surface, benzene evaporates and palmitic acid forms monomolecular film of the solid type. If we wish to cover an area of 500 cm^2 with a monolayer, what volume of solution should be used? The area occupied by one palmitic acid molecule may be taken to be $21 \times 10^{-20}\ m^2$.

ANSWERS

OBJECTIVE TYPE QUESTIONS

1. (c) : Physisorption does not require activation energy since it takes place at low temperature.

2. (a) : Activation of adsorbent means increasing the adsorbing power by making adsorbent's surface rough by subdividing it into smaller pieces or removing gases already adsorbed on it.

3. (a) : The bright cone of the light is known as Tyndall cone. The scattering of light is seen by the microscope.

4. (d) : Gases, liquids or solids can be adsorbed on the solid surfaces.

5. (d) : Addition of protective colloid is a method of prevention of coagulation.

6. (b) : According to Hardy Schulze rule, the coagulating power of an ion depends upon its valency. Higher the valency of ion, greater is its coagulating power.

7. (c) : When movement of particles (electrophoresis) is prevented by some suitable means, it is observed that the dispersion medium begins to move in an electric field. This phenomenon is termed as electroosmosis.

8. (b) : The water obtained from natural sources often contains suspended impurities. Alum is added to such water to coagulate the suspended impurities and make water fit for drinking purposes.

9. (a) : The colloidal particles are in a continuous zig-zag motion due to unbalanced bombardment of the particles by molecules of the dispersion medium.

10. (d) : Adsorption is a spontaneous, exothermic process with decrease in entropy, hence ΔG = –ve, ΔH = –ve and ΔS = –ve.

11. (d) : At higher concentration the aggregated particles called micelles are formed by electrolytes like soap which act as colloidal particles.

12. (b) : The extent of adsorption first increases and then decreases with increase in temperature.

13. (a) : Gel is a colloidal system in which liquid is dispersed in a solid.

14. (c) : It has been found that more readily liquefiable gases are adsorbed more than permanent gases.

15. (a) : The poisonous gases present in coal mines are adsorbed on the activated charcoal.

16. (b) : Chemisorption is favoured at high temperature and physisorption is favoured at low temperature.

17. (b) : The first layer of ions is held firmly and is termed as fixed layer while the second layer is mobile or diffused layer. The potential difference between fixed and diffused layer is called electrokinetic potential or zeta potential.

18. (a) : Lyophobic colloids cannot be prepared by simple mixing of dispersed phase and dispersion medium.

19. (a) : Substances whose molecules aggregate spontaneously in a given solvent to form particles of colloidal dimensions are called associated colloids or micelles.

20. (a) : When an electric field is applied to purify an impure colloidal solution, the process is known as electrodialysis. The ions present in the colloidal solution migrate out to the oppositely charged electrodes.

21. (b) : This is Freundlich isotherm and not Langmuir.

22. (a) : If the dispersed phase is removed completely from the colloidal system, it can be formed again by mixing dispersion medium with it.

23. (d) : Easily liquefiable gases like CO_2, NH_3, SO_2, etc. are more easily adsorbed than the elemental gases like H_2, N_2, O_2, etc.

24. (b) : Ferric hydroxide is a positively charged sol hence ions carrying negative charge can coagulate it. Since PO_4^{3-} has higher negative charge than Cl^- hence it is more effective for coagulation.

25. (a) : Salt solution of gold is being reduced to gold by using a reducing agent like $SnCl_2$.

26. (b) : Pine oil is adsorbed on sulphide ore particles resulting in formation of emulsion and froth.

27. (d) : As excess of KI has been added, I^- ions are adsorbed on AgI forming a fixed layer (and giving it a negative charge). It then attracts the counter ions (K^+) from the medium forming a second layer (diffused layer).

28. (c) : Gas-gas is a true solution.

29. (d) : Lyophilic colloids are highly solvated hence more stable.

30. (a) : In gel, liquid is dispersed in solid.

31. (c) : The method involves both dispersion and condensation. The intense heat of arc vapourises some of the metal which condenses under cold water.

32. (a) : Liquid (water droplets) are dispersed in gas (air) in fog.

33. (a) : In multimolecular colloids the smaller particles aggregate and are held together by van der Waals' forces. *e.g.* sols of gold atoms and sulphur molecules.

34. (c)

35. (a) : The efficiency of coagulation of an electrolyte depends upon its valency. Thus $[Fe(CN)_6]^{4-}$ is the best coagulating agent for $Fe(OH)_3$ sol.

36. (d) : Chemisorption is unimolecular or in one layer.

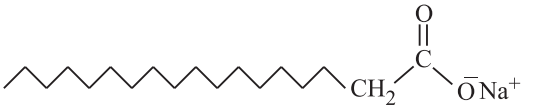
37. (b) : The adsorption of positively charged Fe^{3+} ions by the sol of hydrated ferric oxide results in positively charged colloid.

38. (c) : As_2S_3 is a negatively charged sol. To cause its coagulation, the ions must be positively charged. Greater the magnitude of positive charge, greater will be its coagulating power. Thus $AlCl_3$ containing Al^{3+} ion will be most effective in causing coagulation of As_2S_3.

39. (b) : At CMC, the particles of an electrolyte aggregate and form associated colloids known as micelles.

40. (d) : Tyndall effect is observed only when these two conditions are satisfied.

41. (d) : Distillation cannot be used to remove impurities from colloidal sol.

42. (c) : 

The $RCOO^-$ ion formed in the water contains two parts, a long hydrocarbon chain R (non-polar or hydrophobic tail) and a polar group COO^- (polar or hydrophilic head).

43. (d) : In physisorption as temperature increases, the extent of adsorption decreases thus, I and III are physisorptions.

Chemical adsorption first increases with increase in temperature upto a certain extent and then decreases regularly thus II is chemisorption. In chemisorption, attractive forces between adsorbent and adsorbate molecules are strong chemical bonds, thus enthalpy of adsorption is high and of the order 80-240 kJ/mol. As in IV $\Delta H_{adsorption}$ = 150 kJ/mol, thus it also represents chemical adsorption.

44. (b) : $\frac{x}{m} = kp^{1/n}$

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

Here $\frac{1}{n} = \text{slope}$

$$\text{Slope} = \frac{0.2-0.1}{0.4-0.2} = \frac{2}{4}$$

$$n = \frac{2}{4} = 0.5$$

45. (c) : Example of P (aerosol) are smoke, dust. Example of Q (aerosol) are fog, mist, cloud, etc.

46. (c) : (a) Method I is dialysis and Method II is electrodialysis which is faster than dialysis.

47. (d) : Tyndall effect can be observed in colloidal solution and suspension.

48. (d) : At low pressure, $\frac{x}{m} \propto P$

At high pressure, $\frac{x}{m} \propto P^0$

In the intermediate range of pressure, $\frac{x}{m} \propto P^{\frac{1}{n}}$

49. (a)

50. (d) : According to Freundlich equation

$$\log\left(\frac{x}{m}\right) = \log k + \frac{1}{n}\log P$$

$\therefore$ Plot of log x/m *vs* log P is linear with slope = $1/n$ and intercept = log k.

Thus, $\frac{1}{n} = \tan\theta = \tan 45° = 1$ or $n = 1$

At P = 0.5 atm and k = 10

$$\frac{x}{m} = kP^{1/n}$$

$$\frac{x}{m} = 10 \times (0.5)^1 = 5 \quad \therefore \quad x = 5 \text{ g}$$

51. (c) : Plot of $\log\frac{x}{m}$ *vs* $\log P$ is a straight line with slope $= \frac{1}{n}$

Also, slope = tan θ = tan 14.04° = 0.25

$$\Rightarrow \quad \frac{1}{n} = 0.25 \quad \text{or} \quad n = 4$$

52. (d) : $\frac{x}{m} = kP^{1/n}$

$$\ln\frac{x}{m} = \ln k + \frac{1}{n}\ln P; \quad \text{slope} = \frac{1}{n} = 0$$

Thus, $\frac{x}{m} = kP^0$

53. (c) : In physisorption process, the attractive forces between adsorbate and adsorbent are van der Waals' forces.

54. (a) **55. (d)**

56. (a)

57. (b) : The adsorption of methylene blue on activated charcoal is physical adsorption. It is accompanied by a decrease in enthalpy.

58. (a) : Lesser is the gold number, greater is the protective power.

59. (d) : Charge of $[Fe(CN)_6]^{4-}$ is highest, hence, it will be most effective for the coagulation of positive colloids. More is the coagulating power lesser will be the flocculating value.

60. (a)

61. (c) : Coagulation value is inversely proportional to their flocculating power.

62. (a) : 1 mol Ag^+ will combine with 1 mol I^- to form precipitate of 1 mol AgI.

63. (c) : Desorption is done by heating or by reducing the pressure applied.

64. (a) : Physisorption is exothermic in nature. Therefore, according to Le Chatelier's principle, it occurs readily at low temperature and decreases with increase in temperature. Bonds between surface and adsorbate are weak so when temperature is increased the bonds break easily, so rate will decrease on increasing temperature.

65. (a) : Higher the critical temperature of a gas, greater is the amount of gas adsorbed. Critical temperature (in Kelvin) of the gases :

$$\underset{33.2}{H_2} < \underset{190.6}{CH_4} < \underset{430.3}{SO_2}$$

66. (b) : Since for spontaneous and exothermic process, ΔG = –ve, ΔH = –ve at all temperatures, therefore from $\Delta G = \Delta H - T\Delta S$, ΔS should be –ve. Also adsorption of gas on solid surface gives more orderly arrangement.

67. (d) : Chemisorption first increases with increase of temperature. Physisorption decreases with rise in temperature.

68. (b) : As_2S_3 being negatively charged is coagulated faster by Ba^{2+} ions than by Na^+ ions, according to Hardy Schulze rule, which states that greater the valency of the flocculating ion added, greater is its power to cause precipitation.

69. (c) : Freundlich adsorption isotherm gives an empirical relationship between the quantity of gas adsorbed by unit mass of solid adsorbent $\left(\frac{x}{m}\right)$ and pressure at a particular temperature.

70. (b) : There is no interface between gases due to their complete miscibility.

71. (d) : Soap and detergent are associated colloids as they are formed by the aggregation of a large number of ions due to attraction towards the oppositely charged ions in concentrated solution.

72. (b) : If the dispersion medium is separated from the dispersed phase, the lyophilic sol can be reconstituted by simply remixing with the dispersion medium. That is why these sols are also called reversible sols.

73. (a) : The impact of the molecules of the dispersion medium on the colloidal particles are unequal leading to zig-zag motion *i.e.*, Brownian movement.

74. (a) : Porous or finely divided forms of adsorbent possess greater specific area which is available for adsorption per gram of the adsorbent.

75. (a)

76. (d) : The molecules on the surface have higher energy than those inside. The surface of a solid or a liquid is in a state of strain or tension on account of the unbalanced or residual forces.

77. (a)

78. (b) : Gold number gives a comparative idea of protective power of various lyophilic colloids on a lyophobic colloid. Zeta potential is the potential difference between fixed charged layer and the diffused layer having opposite charge.

79. (b) **80. (b)**

SUBJECTIVE TYPE QUESTIONS

1. Clouds are aerosols and the water particles in air carry some charge over them. Rainfall can occur when two oppositely charged clouds meet. Spraying a sol carrying charge opposite to the one on clouds causes artificial rain.

2. In physisorption, the gas can be adsorbed one over the other by van der Waals' forces, thus is multilayered while chemisorpiton involves formation of a chemical bond, which can be formed only with the layer that is in direct contact with the adsorbent. Therefore, it is mono-layered.

3. Associated colloids.

4. $FeCl_3 + NaOH \longrightarrow \underset{\text{Negatively charged sol}}{Fe_2O_3 \cdot x H_2O/OH^-}$

5. Sea water contains electrolytes. River contains colloids of sand and clay. When they meet the electrolytes neutralise the charge on colloidal particles which results in the precipitation of sand, clay etc. thus, resulting in a delta formation.

6. NH_3 gas will be adsorbed more readily on the surface because it has higher critical temperature than CO_2 gas.

7. The formation of micelles takes place only above a particular temperature called Kraft temperature (T_k).

8. $BaCl_2$ is more effective in causing coagulation of negatively charged colloidal sol.

Because greater the valency of the coagulating ion, greater is its power to bring about coagulation.

9. Medicines are more effective in colloidal form because in this form, these are more easily assimilated due to large surface area.

10. When a powerful beam of light is passed through colloidal solution it exhibits tyndall effect whereas true solution does not.

11. (i) Higher the critical temperature of the gas, more readily it can get adsorbed on the surface of an adsorbent since van der Waals' forces are stronger at this temperature. NH_3 (132°C) has a higher critical temperature than dinitrogen (–147°C) thus, it gets adsorbed more readily than N_2.

(ii) A finely divided substance is more effective as adsorbent because it has more surface area and more number of active sites (active centres) which increases the extent of adsorption.

12. (a) On treating a precipitate of iron (III) hydroxide with a small amount of $FeCl_3$ solution, a reddish brown coloured colloidal solution is formed. In this case, Fe^{3+} ions from ferric chloride are adsorbed by $Fe(OH)_3$ precipitate.

$$Fe(OH)_3 + Fe^{3+} \longrightarrow Fe(OH)_3 \cdot Fe^{3+}$$

Ppt. Electrolyte (ions in) Colloidal sol

(b) When dialysis is persistent and prolonged, traces of electrolyte are also removed. These electrolytes stabilise the colloid and when removed completely, the unstable colloid gets coagulated.

13. Coagulation : The process of aggregating together of colloidal particles into large sized particle which ultimately settles down under the force of gravity as a precipitate is called coagulation.

Coagulation of lyophobic sols can be carried out by adding electrolyte.

14. (i) Activated charcoal in gas masks adsorb the poisonous gases present in air and thus purify the air for breathing.

(ii) Effect of temperature : Chemisorption is an exothermic process but is very slow at lower temperature. High temperature is more favourable thus with increasing temperature, rate of adsorption increases.

15. (i) Animal hides are colloidal in nature. When a hide, which has positively charged particles is soaked in tannin, containing negatively charged colloidal particles, mutual coagulation takes place. This results in the hardening of leather.

(ii) Lyophilic sol is more stable than lyophobic sol because it is highly hydrated in the solution.

16. (i) According to Hardy-Schulze rule, for a negatively charged sol, greater is the valency of the positive ion added, greater is its coagulation power.

Thus, $AlCl_3$ (Al^{3+}) is more effective than $MgCl_2$(Mg^{2+}) in causing coagulation of negatively charged sol.

(ii) Proteins are macromolecules which cannot form multimolecular colloids while sulphur sol have smaller S_8 molecules which can form multimolecular colloids.

17. (i) When the size of the particles lies between 1 to 1000 nm, it behaves as a colloid. If particle size is less than 1 nm, it exists as a true solution and behaves as a crystalloid.

(ii) When $AgNO_3$ solution is added to aqueous KI solution, a negatively charged sol of AgI is formed. This is due to selective adsorption of I^- ions from the dispersion medium on AgI.

$$AgI + I^- \longrightarrow \underset{\text{Negative sol}}{[AgI]I^-}$$

18.

S.No.	Criteria	Physisorption	Chemisorption
(i)	Specificity	It is not specific in nature.	It is highly specific in nature.
(ii)	Temperature dependence	It decreases with increase in temperature. Thus, low temperature is favourable.	It increases with increase in temperature. Thus, high temperature is favourable.
(iii)	Reversibility	Reversible in nature.	Irreversible in nature.
(iv)	Enthalpy change	Low enthalpy of adsorption.	High enthalpy of adsorption.

19. (a)

Multimolecular colloid	Associated colloid
The particles of this type of colloids are aggregates of large number of atoms or smaller molecules. *e.g.*, sulphur sol consists of colloidal particles which are aggregate of S_8 molecules.	They are substances which at low concentration behave as electrolytes but at higher concentration exhibit colloidal behaviour due to formation of aggregated particles.*e.g.*, micelles are associated colloids.

(b)

Coagulation	Peptization
It is the process of settling of colloidal particles.	It is the process of converting a precipitate into colloidal sol.

20. Powdered charcoal is a good adsorbent. It adsorbs the gases on its surface which reduces the pressure of the gas in the enclosed vessel.

21. (i) A colloidal sol in which dispersed phase and dispersion medium attract each other is called lyophilic colloid. *e.g.*, gum.

(ii) The difference in potential between the fixed layer and the diffused layer of opposite charges in a colloidal sol is known as electrokinetic or zeta potential.

(iii) Associated colloids : Micelles are associated colloids. They are substances which at low concentrations behave as strong electrolytes but at higher concentrations exhibit colloidal behaviour due to formation of aggregates.

22. (i) Chemisorption has higher enthalpy of adsorption.

(ii) Physisorption takes place on account of weak van der Waals' forces and no chemical bond is formed, thus the

process is reversible. Chemisorption, on the other hand, involves compound formation, thus it is irreversible in nature.

(iii) The forces operating in physisorption are weak van der Waals' forces.

23. (a) The Brownian movement has a stirring effect which does not permit the particles to settle and thus, it is responsible for the stability of colloidal solutions.

(b) Tyndall effect is not observed in true solutions as the diameter of dispersed particles is very small to disperse the light incident on it.

(c) The water obtained from natural sources often contains suspended impurities. Alum is added to coagulate the suspended impurities and make the water fit for drinking purposes.

24. Multimolecular colloids : When a large number of small molecules or atoms of a substance combine together in a dispersion medium to form aggregates, having size in the colloidal range, the colloidal solutions thus, formed are known as multimolecular colloids. *e.g.*, sulphur sol.

Macromolecular colloids: When macromolecules which have large molecular masses are dispersed in a suitable dispersion medium, they form a solution in which the size of the macromolecule may be in the colloidal range. Such colloids are called macromolecular colloids. *e.g.*, cellulose, starch, etc.

Associated colloids : They are substances which at low concentration behave as electrolytes but at higher concentration exhibit colloidal behaviour due to formation of aggregated particles. *e.g.*, micelles are associated colloids.

25. Effect of temperature : Physisorption decreases with increase of temperature and chemisorption first increases then decreases with increase of temperature.

Surface area : Greater the surface area, greater is the extent of physisorption and chemisorption.

Activation energy : In physisorption, no appreciable activation energy is needed. In chemisorption, sometimes high activation energy is needed.

26. (i) Scattering of light by the colloidal particles takes place and the path of light becomes visible (Tyndall effect).

(ii) The positively charged colloidal particles of ferric hydroxide sol get coagulated by the oppositely charged Cl^- ions provided by NaCl.

(iii) On passing electric current through a sol, colloidal particles start moving towards oppositely charged electrodes where they lose their charge and get coagulated (electrophoresis).

27. (i) (a) Sulphur sol is prepared by the oxidation of H_2S with SO_2.

$$SO_2 + 2H_2S \xrightarrow{\text{Oxidation}} \underset{\text{(Sol)}}{3S} + 2H_2O$$

(b) Gold sol is prepared by Bredig's arc process or by the reduction of $AuCl_3$ with HCHO.

$$2AuCl_3 + 3HCHO + 3H_2O \xrightarrow{\text{Oxidation}} 2Au\ (Sol) + 3HCOOH + 6HCl$$

(ii) In adsorption, there is always a decrease in residual unbalanced forces on the surface. This results in decrease in surface energy which appears as heat. Hence, adsorption is unconditionally an exothermic process.

28. (i) Sol : When solid is dispersed in water, it is called sol, *e.g.*, gold sol.

(ii) Emulsion: When liquid is dispersed in water, it is called emulsion, *e.g.*, milk.

(iii) Foam : When gas is dispersed in water, it is called foam, *e.g.*, soap lather, whipped cream.

29. (i) Washing of clothes involves micelle formation and emulsification.

(ii) Washing of clothes is due to micelle formation. Micelles are formed at a certain minimum temperature known as Kraft's temperature. This temperature is more readily achieved in warm water as compared to cold water.

30. (i) (a) Aggregated particles of associated colloids at high colloidal concentration are called micelles. *e.g.*, soaps.

(b) Colloid of a liquid in a gas is called aerosol *e.g.*, fog, etc.

(ii) Physical adsorption and chemical adsorption both increase with increase in surface area of the adsorbent.

31. The process of settling of colloidal particles is called coagulation of the sol. It is also known as precipitation. Following are the three methods by which coagulation of lyophobic sols can be carried out :

(i) Electrophoresis : In this process, the colloidal particles move towards oppositely charged electrodes and get discharged resulting in coagulation.

(ii) Mixing of two oppositely charged sols : When equal proportions of oppositely charged sols are mixed, they neutralise each other resulting in coagulation.

(iii) Persistent dialysis : On prolonged dialysis, electrolytes present in sol are removed completely and colloids become unstable resulting in coagulation.

32. (i) Hydrosol : It is a colloidal solution in which water is the dispersion medium. *e.g.*, starch solution.

(ii) The developed film is immersed in sodium thiosulphate (hypo) solution which removes uncharged silver bromide as a complex ion. This is known as fixing.

$$AgBr + 2Na_2S_2O_3 \rightarrow Na_3[Ag(S_2O_3)_2] + NaBr$$

After fixing, the film is not sensitive to light.

33. (i) The colloids which protect coagulation of other colloids from the electrolytes are called protective colloids.

Lyophilic colloids are used as a protective colloid for lyophobic colloids.

(ii) Dust particles along with water suspended in air have size smaller than wavelength of visible light and are more effective in scattering light of shorter wavelength, blue light which has smallest wavelength reaches our eyes and the sky looks blue to us.

34. (i) (a) Dispersed phase of smoke = Solid

Dispersion medium of smoke = Gas

(b) Dispersed phase of milk = Fat (liquid)

Dispersion medium of milk = Water (liquid)

(ii) $\frac{x}{m} = kp^{1/n} (n > 1)$

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

where, x is the mass of gas adsorbed on mass m of the adsorbent at pressure p.

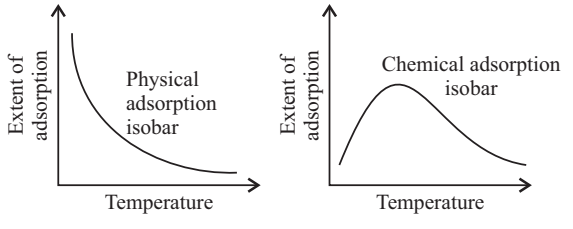
35. (i) The separation of inert gases from a mixture is based on the difference in degree of adsorption of gases by the coconut charcoal.

(ii) Alumina and silica are good adsorbents. They can adsorb even small amount of moisture present in atmosphere.

(iii) Adsorption of gas on solid surface decreases with rising temperature.

36. (a) Adsorption of an adsorbate increases with increasing surface area of adsorbent. Since surface area of a finely divided substance is larger than any other form of adsorbent, hence it is more effective as adsorbent.

(b) Adsorption isobar for physical adsorption shows that the extent of adsorption decreases with the increase in temperature. The adsorption isobar of chemical adsorption shows that the extent of adsorption first increases and then decreases with the increase in temperature. The initial increase in the extent of adsorption with temperature is due to the fact that the heat supplied acts as activation energy required for chemical adsorption which is not required for physical adsorption.



(c) $PV = nRT$

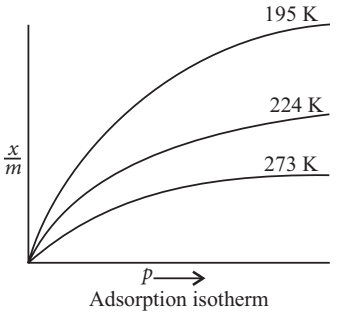
$1.013 \times 0.129 = n \times 0.0821 \times 273$

$\Rightarrow \quad n = \frac{1.013 \times 0.129}{0.0821 \times 273} = 0.00583$ mol

Area occupied $= 0.00583 \times 6.023 \times 10^{23} \times 16.2 \times 10^{-20}$

$= 568 \text{ m}^2 \text{ g}^{-1}$

37. Adsorption isotherm : It is the variation in the amount of gas adsorbed by the adsorbent with pressure at constant temperature.



These curves indicate that on increasing temperature, physical adsorption decreases at a fixed pressure.

Freundlich adsorption isotherm : It is an empirical relationship between the quantity of gas adsorbed by unit mass of solid adsorbent and pressure at a particular temperature.

$\frac{x}{m} = kp^{1/n} (n > 1)$ ...(i)

when, $n = 1, \Rightarrow \frac{x}{m} = kp$ or $\frac{x}{m} \propto p$

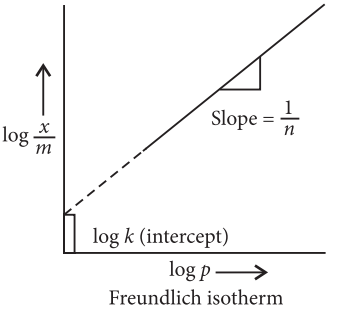
where, x is the mass of gas adsorbed on mass m of the adsorbent at pressure p. k and n are constants which depend on the nature of the adsorbent and the gas at the particular temperature.

Taking log in Eq. (i), gives

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

The validity of Freundlich isotherm can be verified by plotting $\frac{x}{m}$ on y-axis and log p on x-axis.

If it comes to be a straight line, the Freundlich isotherm is valid.



38. (a) For spontaneous process, free energy decreases *i.e.*, ΔG = –ve.

During adsorption process, the gas is adsorbed on the surface of adsorbent, hence it involves the loss of degree of freedom of the gas, therefore, entropy should also decrease during this process *i.e.*, ΔS = –ve.

Now from $\Delta G = \Delta H - T\Delta S$

for adsorption $-\Delta G = \Delta H - [T(-\Delta S)] = \Delta H + T\Delta S$

That means ΔG can be negative if ΔH has sufficiently high negative value, hence the process is exothermic (ΔH = –ve).

(b) In adsorption, there is always a decrease in residual unbalanced forces on the surface. This results in decrease in surface energy which appears as heat. Hence, adsorption is always an exothermic process.

(c) The amount of a gas adsorbed by solid depends on the nature of the gas. In general, higher the critical temperature of a gas, greater is the ease of liquefaction of gas *i.e.*, larger are the van der Waals' forces of attraction. Therefore, greater is the adsorption.

(d) Silica gel and calcium chloride are good adsorbents. Therefore, adsorption of water vapours will occur in both the cases. They will desiccate the vessel completely.

39. (i) Dialysis is the process of removing the electrolyte particles from the colloidal solution by means of diffusion through semi-permeable membrane. The charged nature of the 'sol' is due to ions of the electrolyte adsorbed, which makes it stable. If the electrolyte is completely removed from the sol by excessive dialysis, then the uncharged particles will come nearer to each other and coagulate resulting in precipitation of the 'sol'. Therefore excessive dialysis should be avoided.

(ii) The colloidal particles can't pass through semi-permeable membrane, therefore electrolytes or other molecules from a 'sol' can be separated by diffusing through the membrane. This process of purification of a 'sol' is known as dialysis. One of the application of dialysis is purification of blood using artificial kidney machine. The separation of 'sol' particles from the liquid medium as well as from electrolytes by filtration through an ultrafilter paper such as cellophane is called as ultrafiltration. After separation of 'sol' particles it can be further mixed with the dispersion medium to get pure 'sol'.

40. (i) Number of moles of acetic acid in 100 mL before adding charcoal = 0.05

Number of moles of acetic acid in 100 mL after adding charcoal = 0.049

Number of moles of acetic acid adsorbed on the surface of charcoal = (0.05 – 0.049) = 0.001

Number of molecules of acetic acid adsorbed on the surface of charcoal = $0.001 \times 6.02 \times 10^{23} = 6.02 \times 10^{20}$

Surface area of charcoal = 3.01×10^2 m^2

Area occupied by one molecule of acetic acid on the surface of charcoal = $\frac{3.01\times10^2}{6.02\times10^{20}} = 5\times10^{-19}$ m^2

(ii) Suppose V litre volume of solution is taken,

$W = 4.24 \times V$

Number of atoms = $\frac{W}{\text{Atomic mass}} \times$ Avogadro's number

$= \frac{4.24V}{256} \times 6.023 \times 10^{23}$

Area = $500 \times 10^{-4} = \frac{4.24V}{256} \times 6.023 \times 10^{23} \times 21 \times 10^{-20}$

$V = 0.0000239$ L = 0.0239 cm^3

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