DAY TWENTY THREE

Surface Chemistry

Learning & Revision for the Day

- Adsorption
- Catalysis
- Colloidal State
- Classification of Colloids
- Emulsions

Surface chemistry deals with the phenomenon that occurs at the surface or interfaces. There are several properties of substances, particularly of solids-liquids and solids-gases, which depend upon the nature of the surface of interface.

Adsorption

- The accumulation of molecular species at the surface rather than in the bulk of a solid or liquid is called **adsorption**.
- The solid substance, on the surface of which adsorption occurs are called **adsorbent**.
- The molecular species that get adsorbed on the solid surface due to intermolecular attractions are called **adsorbate**.
- Rate of adsorption decreases with time whereas rate of absorption remains constant with time.
- The removal of the adsorbed substance from a surface is called **desorption**.
- **Sorption** is a process in which adsorption and absorption take place simultaneously e.g. dyes get adsorbed as well as absorbed on the cotton fibres.

Characteristics of Adsorption

Important characteristics of adsorption are as follows :

(i) **Adsorption is specific and selective phenomenon**, which strictly refers to the existence of a higher concentration of any particular component at the surface of a liquid or a solid phase.

(ii) **Adsorption is a exothermic process,** which accompanied with decrease in free energy of the system. In adsorption, there is a decrease in entropy of the system.

As, $\Delta G < 0$ and $\Delta S < 0$,

Therefore, $\Delta H < 0$ $(\because \Delta H = \Delta G + T\Delta S)$

Hence, the adsorption is associated with decrease in enthalpy of the system. Thus, adsorption is always an exothermic process.

(iii) The adsorbed atoms or molecule can be held on the surface of a metal by physical forces or chemical forces due to **residual valence bonds.**

(iv) All solids adsorb gases to some extent. Adsorption is not very pronounced unless an adsorbent possesses a large surface area for a given mass. Various types of charcoals, silica gels, metal, etc., are used as adsorbents.

Types of Adsorption

(i) **Positive Adsorption** If the concentration of an adsorbate at the surface of adsorbent is more than in the bulk of the adjoining phases, it is called positive adsorption.

(ii) **Negative Adsorption** If concentration of an adsorbate at the surface of adsorbent is less than in the bulk of the adjoining phases, it is called negative adsorption.

(iii) **Physisorption and Chemisorption** In physisorption, the particles of the adsorbate are held to the surface of the adsorbent by physical forces such as van der Waals' forces while in chemisorption, the molecules of the adsorbate are held to the surface of the adsorbate by chemical bonds.

Comparison between Physisorption and Chemisorption

S.No.	Physisorption	Chemisorption
1.	van der Waals' forces are very weak.	Chemical bonds are quite strong.
2.	It occurs at low temperature.	It occurs at high temperature.
3.	Heat of adsorption is low, in the range of 20-40 kJ/mol.	Heat of adsorption is high, in the range of 40-400 kJ/mol.
4.	It is reversible process.	It is an irreversible process.
5.	It is an instantaneous process.	It may be rapid or slow.
6.	ΔS is always negative.	ΔS is positive for endothermic process.
7.	In this, multilayer adsorption occurs and thus, adsorbed layer is several molecules thick.	In this, single layer adsorption occurs. Thus, adsorbed layer is only unimolecular in thickness.

NOTE

- Chemical adsorption in some cases is endothermic. For example, adsorption of hydrogen on glass surface and adsorption of highly hydrated solutes on solids.
- As the particles of the adsorbate are held on surface, ΔH and ΔS both are negative and $\Delta H > T\Delta S$. This is true in beginning. As adsorption proceeds ΔH decreases and $T\Delta S$ increases and ultimately $\Delta H = T\Delta S$ and $\Delta G = 0$. This state is called **adsorption equilibrium**.

Factors Affecting Adsorption of Gases on Solids

Adsorption depends upon following number of factors:

1. Nature of Adsorbent

A gas is adsorbed in different amounts on different adsorbents. Hydrogen is strongly adsorbed on nickel surface while it is weakly adsorbed on alumina surface under identical conditions. The adsorption of gases on the surface of metals is called **occlusion**.

2. Nature of Adsorbate

Generally, the more liquefiable a gas is, the more readily it will be adsorbed. Easily liquefiable gases such as NH_3, HCl, Cl_2, SO_2, etc., are readily adsorbed than permanent gases, such as O_2, H_2, N_2 etc.

3. Specific Area of Adsorbent

It is defined as the surface area of adsorbent available for adsorption per gram of the adsorbate. The greater the surface area of the solid, the larger would be its adsorbing capacity.

4. Pressure of Gas

At a given temperature, the extent of adsorption will increase with the increase of pressure of the gas. The variation of extent of adsorption with pressure at a constant temperature is called **adsorption isotherm** at that temperature.

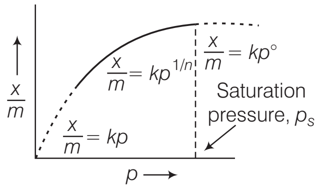
The two important adsorption isotherms are as follows :

(i) **Freundlich Adsorption Isotherm** Freundlich gave the following relation between extent of adsorption $\left(\frac{x}{m}\right)$ and pressure. $\frac{x}{m} = kp^{1/n}$

where, m is the mass of adsorbent and x that of adsorbate.

At low pressure, $\frac{x}{m} = kp \quad (\because n = 1)$

At high pressure, $\frac{x}{m} = kp^{\circ} \quad (\because n = \alpha)$

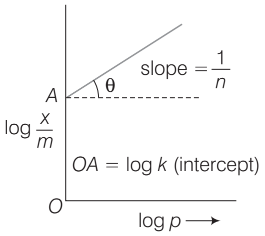


Adsorption isotherm for different values of n

Taking logarithm of the equation $\frac{x}{m} = kp^{1/n}$ gives,

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

Graph between $\log\left(\frac{x}{m}\right)$ and $\log p$ is a straight line with slope $\frac{1}{n}$ and intercept $\log k$.



Freundlich adsorption isotherm

(ii) **Langmuir Isotherm** Freundlich isotherm fails at high pressure and is only for physical adsorption.

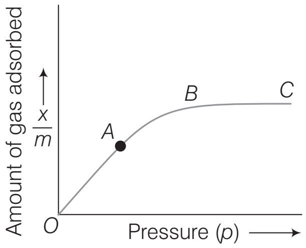
Langmuir isotherm is represented as

$$\frac{x}{m} = \frac{ap}{1+bp} \qquad (a \text{ and } b \text{ are constants})$$

At very high pressure, $(bp >> 1)\ \frac{x}{m} = \frac{a}{b} = \text{constant}$

At very low pressure, $(bp << 1)\ \frac{x}{m} = ap$

$$\therefore \qquad \frac{x}{m} \propto p$$



Adsorption isotherm between pressure (p) and amount of gas adsorbed (x/m)

- **Freundlich adsorption isotherm** and **Langmuir adsorption isotherm** are applicable to adsorptions from solutions.

  Freundlich adsorption isotherm, $\frac{x}{m} = kC^{1/n} \quad (n > 1)$

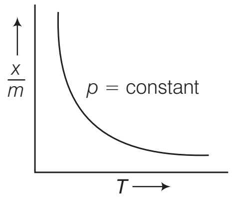
  Langmuir adsorption isotherm, $\frac{x}{m} = \frac{aC}{(1+bC)}$

  Langmuir adsorption isotherm is applicable only to chemisorption.

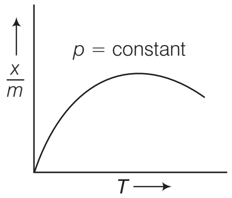
5. Temperature

Low temperature favours the physical adsorption, but on increasing temperature, physical adsorption decreases.

- Whereas in case of chemisorption, x/m, initially increases with temperature and then decreases. The initial increase is due to the fact that chemisorption requires activation energy.
- The graph between extent of adsorption $\left(\frac{x}{m}\right)$ and temperature T is called **adsorption isobar**.



Physical adsorption



Chemical adsorption

Catalysis

A substance that can influence the rate of a chemical reaction but is not consumed during the reaction is known as **catalyst**. The catalyst change the rate of reaction by providing an alternate path of different activation energy. This phenomenon is known as **catalysis**.

Catalysis can be divided into following groups :

(i) **Homogeneous Catalysis** When the reactants and catalyst are in same phase, the process is said to be homogeneous catalysis.

e.g. $2SO_2(g) + O_2(g) \xrightarrow{NO(g)} 2SO_3(g)$

(ii) **Heterogeneous Catalysis** When the reactants and catalyst are in different phase the process is said to be heterogeneous catalysis.

$$N_2(g) + 3H_2(g) \xrightarrow[\text{divided Fe}(s)]{\text{Finely}} 2NH_3(g)$$

(iii) **Auto-catalysis** The phenomenon in which one of the products formed during the reaction acts as catalyst for the reaction is known as auto-catalysis.

e.g. $2KMnO_4 + 5H_2C_2O_4 + 3H_2SO_4 \longrightarrow$
$K_2SO_4 + 2MnSO_4 + 8H_2O + 10CO_2$

In this reaction, Mn^{2+} ions act as auto-catalyst.

(iv) **Induced Catalysis** In this type of catalysis, one reaction influences the rate of other reaction, which does not occur under ordinary conditions, e.g. the reduction of $HgCl_2$ by oxalic acid is slow but becomes faster if reduction is made in mixture of $KMnO_4$ and $HgCl_2$; where both are reduced. Reduction of $KMnO_4$ thus induces the reduction of $HgCl_2$.

Promoters and Inhibitors

Promoters are the substances which can increase the efficiency of a catalyst. These are also known as coenzymes or activators. Inhibitors are the substances which can make the catalyst inactive, e.g. Mg^{2+} acts as activators for many enzymes while $C_2O_4^{2-}$ and F^- act as inhibitors as they form complex with Mg^{2+}.

Characteristics of Catalysts

Some important characteristics of catalysts are discussed below:

- They are temporarily involved in a reaction, providing an alternative reaction path of lower activation energy than that for the uncatalysed reaction.
- They catalyse both forward and backward reactions to the same extent in a reversible reaction and thus have no effect on the equilibrium constant.
- The catalyst remains unchanged in amount and chemical composition at the end of the reaction. It may undergo some physical change.
- Only a small quantity of the catalyst is generally needed. One mole of colloidal platinum in 10^8 L can catalyse decomposition of H_2O_2.
- In certain reactions, the rate of the reaction is dependent on the concentration of the catalyst. e.g. Rate of inversion of cane sugar is dependent on the concentration of H^+ used as catalyst.

- Rate of the reaction in certain heterogeneous reaction varies with surface area of the catalyst. Hence, finely divided metals are preferred in the form of catalyst.
- The catalyst does not initiate the reaction and are specific in their action, e.g. starting from H_2 and CO, 3 different products are possible using different catalysts as

$$CO(g) + 3H_2(g) \xrightarrow{Ni} CH_4(g) + H_2O(g)$$

$$CO(g) + 2H_2(g) \xrightarrow{Cu/ZnO\text{-}Cr_2O_3} CH_3OH(g)$$

$$CO(g) + H_2(g) \xrightarrow[250°C]{Cu} HCHO$$

Activity and Selectivity of Catalyst

- Activity is the ability of catalysts to accelerate chemical reactions.
- **Activity** of catalyst depends upon the strength of chemisorption to a large extent.
- **Selectivity** means a given substance can act as catalyst only in a particular reaction and not for all reactions. e.g.

(i) $CO(g) + 3H_2(g) \xrightarrow{Ni} CH_4(g) + H_2O(g)$

(ii) $CO(g) + H_2(g) \xrightarrow{Cu} HCHO(g)$

(iii) $CO(g) + 2H_2(g) \xrightarrow{Cu/ZnO–Cr_2O_3} CH_3OH(g)$

Enzyme Catalysis

- Enzymes are biochemical catalysts. They are proteins and extremely specific in nature.

e.g. $NH_2CONH_2 + H_2O \xrightarrow{Urease} 2NH_3 + 2CO_2$

- Common steps for all enzyme catalysed reactions are

(i) $E + S \rightleftharpoons ES$ (fast, reversible)

(ii) $ES \longrightarrow E + P$ (slow, rate determining)

Some important reactions involving enzymes are given below in table :

Reaction	Catalyst
$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$	Invertase
$\underset{\text{Maltose}}{C_{12}H_{12}O_{11}} + H_2O \longrightarrow \underset{\text{Glucose}}{2C_6H_{12}O_6}$	Maltase
$\underset{\text{Starch}}{2(C_6H_{10}O_5)_n} + nH_2O \longrightarrow \underset{\text{Maltose}}{n(C_{12}H_{22}O_{11})}$	Diastase
$\underset{\text{Glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{Ethanol}}{2C_2H_5OH} + CO_2(g)$	Zymase
$\underset{\text{Urea}}{NH_2CONH_2} + H_2O \longrightarrow 2NH_3 + CO_2(l)$	Urease
$CO_2(aq) + H_2O \rightleftharpoons H^+(aq) + HCO_3^-(aq)$	Carbonic anhydrase (in human body)
N_2 (atmospheric) → NH_3	Nitrogenase

Colloidal State

A substance is said to be in the colloidal state, when it is dispersed in another medium in form of very small particles having diameter between 10^{-9} m to 10^{-6} m.

Distinction between True Solutions, Colloidal Solutions and Suspensions

Depending upon the size of the particles, there are three different types of solutions *viz*, **true solutions, suspensions** and **colloidal solutions.**

Properties	**True solutions** (Molecular solutions)	**Colloidal solutions** (Colloidal dispersion)	**Suspensions** (Coarse dispersion)
Size	Less than 1 nm or 10^{-7} cm	Between 1 nm and 1000 nm or 10^{-7}- 10^{-4} cm	Greater than 1000 nm or 10^{-4} cm
Visibility	Invisible even under ultra-microscope	Visible only under ultra-microscope	Visible even by naked eye
Diffusion	Diffuse readily through parchment membrane	Diffuse slowly through parchment membrane	No diffusion
Filtration	Possible through filter paper and parchment membrane	Possible through filter paper but not through parchment membrane	Impossible through filter paper and parchment membrane
Scattering of light	No scattering	Scattering takes place (Tyndall effect)	Do not show Tyndall effect
Settling	Do not settle	Do not settle but settle when centrifuged	Settle under gravity at normal condition
Nature	Homogeneous	Heterogeneous	Heterogeneous
Brownian motion	Do not show	Show	May show
Appearance	Clear	Generally clear or opaque	Opaque

Dispersed Phase and Dispersion Medium

The **colloidal system** is made of two phases :

- The substance distributed as the colloidal particles, called the **dispersed phase**.
- The phase in which the colloidal particles are scattered, called **dispersion medium**.

The dispersed phase or dispersion medium can be a gas, liquid or solid. There are eight types of colloidal system.

Classification of Colloids

Colloids can be classified in a number of ways based upon some of their important characteristics as given below:

1. Based upon Appearance

On this basis, colloids can be classified into eight classes. These are as follows:

Colloidal system	Dispersed phase	Dispersion medium	Examples
Foam	Gas	Liquid	Soda water, froth, shaving cream
Solid foam	Gas	Solid	Foam rubber, cork
Aerosol	Liquid	Gas	Fog, mist, clouds
Emulsion	Liquid	Liquid	Milk, hair cream
Solid emulsion (gel)	Liquid	Solid	Butter, cheese
Aerosol of solids	Solid	Gas	Dust in air, smoke
Sol	Solid	Liquid	Paint, ink, colloidal gold,
Solid sol	Solid	Solid	Ruby glass, some gem stones, alloys, rock salt

2. Based Upon Charge

The colloids can be classified into **positive** or **negative** colloids according to the charge present on the dispersed phase particles.

3. Lyophilic and Lyophobic Colloids

On this basis of affinity with solvent, colloids can be classified into following two types.

(i) **Lyophilic colloids** represent such colloidal systems in which the particles of dispersed phase have great affinity for the dispersion medium. These are reversible colloids, e.g. gum, gelatin, rubber, proteins etc.

(ii) **Lyophobic colloids** represent such colloidal systems in which particles of the dispersed phase have no affinity for the dispersion medium. These are irreversible, e.g. sols of metals and their insoluble compounds like sulphides and oxides. Lyophobic colloids are less stable due to the presence of electric charge on their particles.

If water is the dispersion medium, the terms used are hydrophilic and hydrophobic colloids. On the otherhand, lyophilic colloids are stable due to their presence of charge as well as their extensive solvation.

4. Based on Molecular Size

On this basis, colloids are classified into three types :

(i) **Multimolecular colloids** are the colloids in which colloidal particles consist of aggregate of atoms or small molecules with diameter less than 10^{-9} m or 1 nm, e.g. a sol of gold, a sol of sulphur.

(ii) **Macromolecular colloids** are the colloids in which colloidal particles themselves are large molecules.

(iii) **Associated colloids or micelles** are the substances which behave as normal electrolytes at low concentration but as colloids at higher concentration. This is because at higher concentration, they form associated particles called micelles, e.g. soap and synthetic detergents.

The concentration above which micelle formation occurs, is called **CMC** (critical micelle concentration) and the temperature above which micelle formation occurs is called **Kraft temperature**.

The colligative properties of colloidal systems are low due to aggregation. Hence, all colloidal solutions exhibit very low osmotic pressure, very small elevation in boiling point and depression in freezing point.

Preparation of Lyophobic Solution

Lyophilic colloids may be prepared by simply warming the solid with the liquid dispersion medium. On the other hand, lyophobic colloids have to be prepared by special methods. Substances are converted into colloidal solutions by the two methods.

- **Dispersion methods** involve the breaking of bigger particles to the size of colloidal particles. The various dispersion methods are :

  (i) **Electro-disintegration method** (Bredig's arc method) By this method, colloidal solutions of metals like gold, silver etc., are obtained.

  (ii) **Peptisation** : e.g.

$$\underset{\text{Fresh ppt.}}{Fe(OH)_3} + \underset{\text{Electrolyte}}{FeCl_3} \longrightarrow \underset{\text{Colloid}}{[Fe(OH)_3Fe]^{3+}} + 3Cl^-$$

- **Condensation methods** involve the growing of size of the dispersed phase or the size of colloidal particles.

  (i) By double decomposition

$$As_2O_3 + 3H_2S \longrightarrow \underset{\text{Colloidal solution}}{As_2S_3} + 3H_2O$$

  (ii) By hydrolysis

$$FeCl_3 + 3H_2O \longrightarrow \underset{\text{Colloidal solution}}{Fe(OH)_3} + 3HCl$$

  (iii) By oxidation

$$H_2S + 2HNO_3 \longrightarrow 2H_2O + 2NO_2 + \underset{\text{Colloidal}}{S}$$

Purification of Colloidal Solutions

The following methods are commonly used to purify the colloids.

(i) **Dialysis** It is the process of removing small molecules or ions from a colloidal sol by diffusion through a semipermeable membrane. In this process, impure colloidal solution is placed in a bag of semipermeable membrane, dipping in water, the ions diffuse through membrane. Ferric hydroxide sol can be purified by this method.

(ii) **Electrodialysis** If dialysis is carried out under the influence of electric field, it is called electrodialysis. This speeds up the migration of ions to the opposite electrodes.

(iii) **Ultrafiltration** Separation of sol particles from the liquid medium and electrolytes by filtration through an ultrafilter is called **ultrafiltration**.

(iv) **Ultra-centrifugation** In ultra-centrifuge, the colloidal particles settle down at the bottom and impurities remain in the solution.

Properties of Colloidal Solutions

The important properties of the colloidal solutions are given below:

(i) **Brownian Movement** Colloidal particles are always in a state of rapid random motion, which is termed as Brownian movement.

(ii) **Tyndall Effect** When a strong and converging beam of light is passed through a colloidal solution, its path becomes visible due to scattering of light by particles. It is called Tyndall effect.

(iii) **Electrophoresis** The phenomenon, involving the migration of colloidal particles under the influence of electric field towards the oppositely charged electrode, is called electrophoresis. Sedimentation potential or Dorn effect is the reverse of electrophoresis and set up when a particle is forced to move in a resting liquid.

(iv) **Coagulation or Flocculation** The precipitation of particles of the dispersed phase in a sol is known as **coagulation**.

The minimum amount of an electrolyte required to cause precipitation of one litre of a colloidal solution is called **coagulation value** or **flocculation value.** The reciprocal of coagulation value is regarded as the **coagulating power.** Coagulation can be achieved by following means,

(a) electrophoresis
(b) mixing two oppositely charged sol
(c) boiling
(d) addition of electrolytes, etc.

Out of the above methods, the last one is most common and governed by **Hardy-Schulze rule**.

(i) **According to this rule**, Higher the valency of the active ion, the greater will be its power to precipitate the sol. e.g. order of coagulating power is

$$Al^{3+} > Ba^{2+} > Na^{+} \text{ for negative solution}$$

$$PO_4^{3-} > SO_4^{2-} > Cl^{-} \text{ for positive solution}$$

(ii) **Protective Action** As lyophobic sols are unstable (e.g. Au, Ag) and get easily precipitated, the addition of lyophilic colloids like gums, soaps etc., makes it difficult. The process is known as **protection** and the lyophilic colloids are termed as **protective colloids.**

(iii) **Gold Number** It is the minimum weight (in mg) which must be added to 10 mL of given gold sol, so that no coagulation of it takes place when 1 mL of 10% NaCl solution is rapidly added to it.

Emulsions

These are the colloidal solutions of two immiscible liquids in which the liquids act as the dispersed phase as well as the dispersion medium.

Types of Emulsions

There are two types of emulsions :

(i) **Oil in water type**, in which tiny droplets of liquid fat are dispersed in water. e.g. milk

(ii) **Water in oil type**, in which water being dispersed in lubricating oil. e.g. stiff greases

- **Emulsifying Agents** During the preparation of emulsion, a small amount of some substances such as soap, gum, agar and protein etc., are added to stabilise the emulsion. These substances are known as emulsifying agents.
- **Breaking of Emulsions** Emulsions can be broken into constituent liquids by heating, freezing, centrifuging or chemical destruction of emulsifying agent.

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 Adsorbed acetic acid on activated charcoal is

(a) adsorber (b) adsorbent (c) adsorbate (d) absorber

2 Which of the following is not applicable to the phenomenon of adsorption?

(a) $\Delta H > 0$ (b) $\Delta G < 0$ (c) $\Delta S < 0$ (d) $\Delta H < 0$

3 Which one of the following characteristics is associated with adsorption? **→ NEET 2016, Phase I**

(a) ΔG, ΔH and ΔS all are negative
(b) ΔG and ΔH are negative but ΔS is positive
(c) ΔG and ΔS are negative but ΔH is positive
(d) ΔG is negative but ΔH and ΔS are positive

4 Which of the following statements is correct for the spontaneous adsorption of a gas? **→ CBSE-AIPMT 2014**

(a) ΔS is negative and therefore, ΔH should be highly positive
(b) ΔS is negative and therefore, ΔH should be highly negative
(c) ΔS is positive and therefore, ΔH should be negative
(d) ΔS is positive and therefore, ΔH should also be highly positive

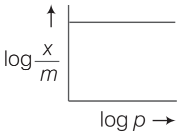
5 Adsorption in multilayer, occurs in case of

(a) physical adsorption (b) chemical adsorption
(c) Both (a) and (b) (d) None of these

6 Which one of the following characteristics is not correct for physical adsorption?

(a) Adsorption on solids is reversible
(b) Adsorption increases with increase in temperature
(c) Adsorption is spontaneous
(d) Both enthalpy and entropy of adsorption are negative

7 Which one of the following graphs represents Freundlich adsorption isotherm?

(a)


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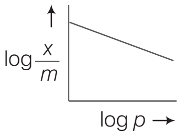
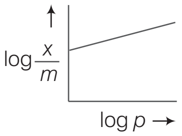
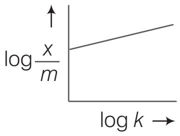


(c)


(d)


8 The Langmuir adsorption isotherm is deduced using the assumption

(a) the adsorption takes place is monolayer
(b) the adsorption sites are equivalent in their ability to adsorb the particles
(c) the heat of adsorption varies with coverage
(d) the adsorbed molecules interact with each other

9 At high pressure, Langmuir adsorption isotherm takes the form

(a) $\frac{x}{m} = \frac{ap}{1+bp}$ (b) $\frac{x}{m} = \frac{a}{b}$
(c) $\frac{x}{m} = ap$ (d) $\frac{m}{x} = \frac{b}{a} + \frac{1}{ap}$

10 In Freundlich adsorption isotherm, the value of $1/n$ is **→ CBSE-AIPMT 2012**

(a) between 0 and 1 in all cases
(b) between 2 and 4 in all cases
(c) 1 in case of physical adsorption
(d) 1 in case of chemisorption

11 If x is amount of adsorbate and m is amount of adsorbent, which of the following relations is not related to adsorption process? **→ CBSE-AIPMT 2011**

(a) $\frac{x}{m} = f(T)$ at constant p (b) $p = f(T)$ at constant $\left(\frac{x}{m}\right)$
(c) $\frac{x}{m} = p \times T$ (d) $\frac{x}{m} = f(p)$ at constant T

12 Which one of the following is an example for homogeneous catalysis?

(a) Manufacture of sulphuric acid by contact process
(b) Manufacture of ammonia by Haber's process
(c) Hydrolysis of sucrose in presence of dilute hydrochloric acid
(d) Hydrogenation of oil

13 Which of the following process does not occur at the interface of phases?

(a) Crystallisation (b) Heterogeneous catalysis
(c) Homogeneous catalysis (d) Corrosion

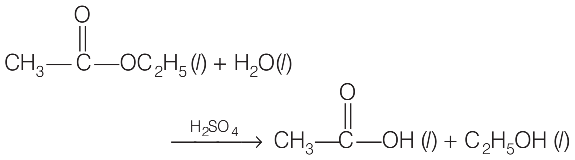
14 In which of the following reactions heterogeneous catalysis involved?

I. $2SO_2(g) + O_2(g) \xrightarrow{NO(g)} 2SO_3(g)$
II. $2SO_2(g) + O_2(g) \xrightarrow{Pt(s)} 2SO_3(g)$
III. $N_2(g) + 3H_2(g) \xrightarrow{Fe(s)} 2NH_3(g)$
IV. $CH_3COOCH_3(l) + H_2O(l) \xrightarrow{HCl(l)} CH_3COOH(aq) + CH_3OH(aq)$

(a) II and III (b) II, III and IV (c) I, II and III (d) Only IV

15 Which of the following reactions is an example of heterogeneous catalysis?

(a) $O_3 + O \xrightarrow{Cl} 2O_2$ (gas phase)
(b) $2CO(g) + O_2(g) \xrightarrow{NO} 2CO_2(g)$

(c) 

$CH_3-\overset{\overset{O}{||}}{C}-OC_2H_5(l) + H_2O(l) \xrightarrow{H_2SO_4} CH_3-\overset{\overset{O}{||}}{C}-OH(l) + C_2H_5OH(l)$

(d) $CO(g) + 2H_2(g) \xrightarrow{Cu,\ ZnO\text{-}Cr_2O_3} CH_3OH(l)$

16 According to the adsorption theory of catalysis, the speed of reaction increases because

(a) adsorption lowers the activation energy of the reaction
(b) the concentration of reactant molecules at the active centres of the catalyst becomes high due to adsorption
(c) in the process of adsorption, the activation energy of the molecules becomes large
(d) adsorption produces heat, which increases the speed of the reaction

17 The efficiency of enzyme catalysis is due to its capacity to

(a) form a strong enzyme-substrate complex
(b) change the shape of the substrate
(c) lower the activation energy of the reaction
(d) form a colloidal solution in water

18 The enzyme which can catalyse the conversion of glucose to ethanol is

(a) zymase (b) invertase (c) maltase (d) diastase

19 Colloidal solution of gold prepared by different methods are of different colours because of

(a) variable valency of gold
(b) different concentrations of gold particles
(c) impurities produced by different methods
(d) different diameters of colloidal gold particles

20 Which one of the following statements is incorrect about enzyme catalysis? **→ CBSE-AIPMT 2012**

(a) Enzymes are mostly proteinous in nature
(b) Enzyme action is specific
(c) Enzymes are denaturated by UV-rays and at high temperature
(d) Enzymes are least reactive at optimum temperature

21 Fog is a colloidal solution of **→ NEET 2016, Phase I**

(a) Gas in liquid (b) Solid in gas
(c) Gas in gas (d) Liquid in gas

22 Which one of the following forms micelles in aqueous solution above certain concentration?

(a) Urea
(b) Dodecyl trimethyl ammonium chloride
(c) Pyridinium chloride
(d) Glucose

23 Which of the following forms cationic micelles above certain concentrations?

(a) Sodium ethyl sulphate
(b) Sodium acetate
(c) Urea
(d) Cetyltrimethyl ammonium bromide

24 Lyophilic colloids are stable due to

(a) charge on particles
(b) large size of the particle
(c) small size of the particles
(d) layer of dispersion medium on the particles

25 Which of the following is not correct?

(a) Milk is a naturally occurring emulsion
(b) Gold sol is a lyophilic sol
(c) Physical adsorption decreases with rise in temperature
(d) Chemical adsorption is unilayered

26 The Brownian motion is due to

(a) temperature fluctuation within the liquid phase
(b) attraction and repulsion between charges on the colloidal particles
(c) impact of the molecules of the dispersion medium
(d) convectional currents

27 Tyndall effect is more pronounced in

(a) hydrophilic sols (b) hydrophobic sols
(c) lyophilic sols (d) Both (a) and (b)

28 Blood may be purified by

(a) dialysis (b) electro-osmosis
(c) coagulation (d) filtration

29 Which of the following process is responsible for the formation of delta at a place where rivers meet the sea?

(a) Emulsification (b) Colloid formation
(c) Coagulation (d) Peptisation

30 Which of the following electrolytes is least effective in coagulating ferric hydroxide solution?

(a) KBr (b) K_2SO_4
(c) K_2CrO_4 (d) $K_4[Fe(CN)_6]$

31 On which of the following properties does the coagulating power of an ion depend? **→ NEET 2018**

(a) Both magnitude and sign of the charge on the ion
(b) Size of the ion alone
(c) The magnitude of the charge on the ion alone
(d) The sign of charge on the ion alone

32 The concentration of electrolyte required to coagulate a given amount of As_2S_3 sol is minimum in case of

(a) K_2SO_4 (b) $Al(NO_3)_3$ (c) $Mg(NO_3)_2$ (d) KNO_3

33 Which is more powerful to coagulate the negative colloid?

(a) $ZnSO_4$ (b) Na_3PO_4 (c) $AlCl_3$ (d) $K_4[Fe(CN)_6]$

34 The coagulation values of $AlCl_3$ and NaCl are 0.093 and 52 respectively. The ratio of coagulating power of both will be

(a) 0.093 : 1 (b) 52 : 1 (c) 559 : 1 (d) 1.788 : 1

35 Alum helps in purifying water by

(a) forming Si complex with dirt particles
(b) sulphate part which combines with dirt and removes it
(c) making mud water soluble
(d) aluminium ions which coagulates the mud particle

36 Bleeding due to a cut can be stopped by applying ferric chloride solution in the laboratory. This is due to

(a) coagulation of negatively charged blood particles by Fe^{3+} ions
(b) coagulation of positively charged blood particles by Cl^- ions
(c) reaction taking place between ferric ions and the haemoglobin forming a complex
(d) common element, iron, in both $FeCl_3$ and haemoglobin

37 The protecting power of lyophilic colloidal sol is expressed in terms of **→ CBSE-AIPMT 2012**

(a) coagulation value (b) gold number
(c) critical micelle concentration (d) oxidation number

38 The gold numbers of some colloidal solutions are given below:

Colloidal solution	Gold number
A	0.01
B	2.5
C	20

The protective nature of these colloidal solutions follow the order

(a) $C > B > A$ (b) $A > B > C$
(c) $A = B = C$ (d) $B > A > C$

39 Milk is

(a) fat dispersed in water (b) fat dispersed in milk
(c) fat dispersed in fat (d) water dispersed in milk

40 Which of the following substances will precipitate the negatively charged emulsions?

I. KCl II. glucose III. urea IV. NaCl

The correct answer is

(a) I and II (b) I and III (c) I and IV (d) II and III

41 An emulsion cannot be broken by……and……

I. heating
II. adding more amount of dispersion medium
III. freezing
IV. adding emulsifying agent

The correct answer is

(a) I and II (b) II and III (c) II and IV (d) I, II and III

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 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

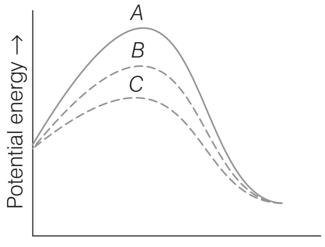
2 On adding 1 mL of solution of 10% NaCl to 10 mL of gold sol in the presence of 0.25 g of starch, the coagulation is just prevented. The gold number of starch is

(a) 0.25 (b) 0.025 (c) 25 (d) 250

3 The density of gold is 19 g/cm^3. If 1.9×10^{-4} g of gold is dispersed in 1 L of water to give a sol having spherical gold particles of radius 10 nm, then the number of gold particles per mm^3 of the sol will be

(a) 1.9×10^{12} (b) 6.3×10^{14} (c) 6.3×10^{10} (d) 2.4×10^{6}

4 In homogeneous catalytic reactions, there are three alternative paths *A*, *B* and *C* (shown in the figure). Which one among the following option indicates the relative ease with which the reaction can take place?



(a) $A > B > C$ (b) $C > B > A$
(c) $B > C > A$ (d) $A = B = C$

5 Adsorption is accompanied by the evolution of heat, so according to Le-Chatelier's principle, the amount of substance adsorb with temperature as

(a) increases with decrease in *T*
(b) increases with increase in *T*
(c) decreases with decrease in *T*
(d) None of the above

6 For the following reaction,

$$C_6H_{12}O_6(aq) + H_2(g) \rightleftharpoons C_6H_{14}O_6(g)$$

Which one of the following is not affected by the addition of catalyst?

(a) Rate of forward reaction
(b) Rate of backward reaction
(c) Time required to reach the equilibrium
(d) Spontaneity

7 Which among the following statements are correct with respect to adsorption of gases on a solid?

I. The extent of adsorption is equal to kp^n according to Freundlich isotherm.
II. The extent of adsorption is equal to $kp^{1/n}$ according to Freundlich isotherm.
III. The extent of adsorption is equal to $\left(\frac{1+bp}{ap}\right)$ according to Langmuir isotherm
IV. The extent of adsorption is equal to $\frac{ap}{(1+bp)}$ according to Langmuir isotherm

(a) I and II (b) I and IV
(c) II and III (d) II and IV

8 Which of the following factors are responsible for the increase in the rate of surface catalysed reaction?

I. A catalyst provides proper orientation for the molecules to react.

II. Heat of adsorption of reactants on a catalyst, helps reactant molecules to overcome activation energy.

III. The catalyst increases the activation energy of the reaction.

IV. Adsorption increases the local concentration of reactant molecules on the surface of the catalyst.

Select the correct answer using the codes given below:

(a) I and II (b) I and II (c) I, II and IV (d) I and III

9 Which one of the following reactions is an example of auto-catalysis?

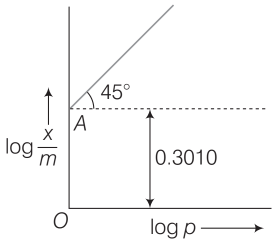
(a) $2AsH_3(g) \longrightarrow 2As(g) + 3H_2(g)$

(b) $N_2(g) + 3H_2(g) \xrightarrow{Fe(s)} 2NH_3(g)$

(c) $2SO_2(g) + O_2(g) \xrightarrow{NO(g)} 2SO_3(g)$

(d) $C_{12}H_{22}O_{11}(l) + H_2O(l) \xrightarrow{H^+} C_6H_{12}O_6(l) + C_6H_{12}O_6(l)$

10 Graph between $\log\left(\frac{x}{m}\right)$ and $\log p$ is a straight line at angle 45° with intercept OA as shown. Hence, $\left(\frac{x}{m}\right)$ at a pressure of 0.2 atm is



(a) 0.2 (b) 0.4
(c) 0.6 (d) 0.8

11 If a freshly formed ppt. of SnO_2 is peptised by a small amount of NaOH, these colloidal particles may be represented as

(a) $[SnO_2]\,SnO_3^{2-} : 2Na^+$ (b) $[SnO_2]\,Sn^{4+} : O^{2-}$
(c) $[SnO_2]\,Na^+ : OH^-$ (d) $[SnO_2]\,Sn^{4+} : OH^-$

12 $[AgI]\,I^-$ colloidal sol can be coagulated by the addition of a suitable cation. 1 mol of $[AgI]\,I^-$ requires mol of $AgNO_3$, $Pb(NO_3)_2$ and $Fe(NO_3)_3$ as

(a) 1, 1, 1 (b) 1, 2, 3
(c) $1, \frac{1}{2}, \frac{1}{3}$ (d) 6, 3, 2

13 50 mL of 1M oxalic acid is shaken with 0.5g wood charcoal. The final concentration of the solution after adsorption is 0.5 M. What is the amount of oxalic acid absorbed per gram of carbon?

(a) 3.45g (b) 6.30 g
(c) 3.15g (d) None of these

14 The gold number of gelatin, haemoglobin, and sodium acetate are 0.005,0.05 and 0.7 respectively. The protective actions will be in the order of

(a) gelatin < haemolgobin < sodium acetate
(b) gelatin > haemoglobin > sodium acetate
(c) haemoglobin > gelatin >sodium acetate
(d) sodium acetate > gelatin > haemoglobin

15 The volume of a colloidal particle, V_C as compared to the volume of a solute particle in a true solution V_S, could be

(a) $\frac{V_C}{V_S} \approx 10^3$ (b) $\frac{V_C}{V_S} \approx 10^{23}$
(c) $\frac{V_C}{V_S} \approx 10^{-3}$ (d) $\frac{V_C}{V_S} \approx 1$

ANSWERS

SESSION 1	**1.** (c)	**2.** (a)	**3.** (a)	**4.** (b)	**5.** (a)	**6.** (b)	**7.** (c)	**8.** (a)	**9.** (b)	**10.** (a)
	11. (c)	**12.** (c)	**13.** (c)	**14.** (a)	**15.** (d)	**16.** (a)	**17.** (c)	**18.** (a)	**19.** (d)	**20.** (d)
	21. (d)	**22.** (b)	**23.** (d)	**24.** (d)	**25.** (b)	**26.** (c)	**27.** (b)	**28.** (a)	**29.** (c)	**30.** (a)
	31. (a)	**32.** (b)	**33.** (c)	**34.** (c)	**35.** (d)	**36.** (a)	**37.** (b)	**38.** (b)	**39.** (a)	**40.** (c)
	41. (c)									
SESSION 2	**1.** (d)	**2.** (d)	**3.** (d)	**4.** (b)	**5.** (a)	**6.** (d)	**7.** (d)	**8.** (c)	**9.** (a)	**10.** (b)
	11. (a)	**12.** (c)	**13.** (b)	**14.** (b)	**15.** (a)					

Hints and Explanations

SESSION 1

1 Adsorbed acetic acid on charcoal is called adsorbate.

2 For adsorption, the value of ΔH should not be greater than 0.

3 Adsorption is a spontaneous process that occurs with release in energy and decrease in the randomness (i.e. entropy) of the adsorbed substance.

For a spontaneous process, ΔG must be negative.

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

As the process is exothermic and randomness of molecule (entropy) decreases hence, both ΔH and ΔS will be negative as well.

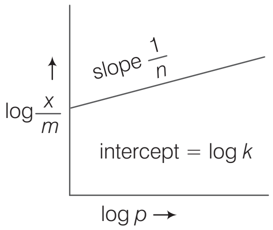
4 ΔS [change in entropy] and ΔH [change in enthalpy] are related by the equation, $\Delta G = \Delta H - T\Delta S$ [Here, ΔG = change in Gibbs free energy]

For adsorption of a gas, ΔS is negative because randomness decreases. Thus, in order to make ΔG negative [for spontaneous reaction], ΔH must be highly negative because reaction is exothermic. Hence, for the adsorption of a gas, if ΔS is negative, then ΔH should be highly negative.

5 Physical adsorption involves multilayer adsorption.

6 Extent of adsorption decreases with increase in temperature.

7 When we plot a graph between $\log(x/m)$ and $\log p$, a straight line with positive slope is obtained. This graph represents the Freundlich adsorption isotherm.



Graph of Freundlich adsorption isotherm

8 Main points of Langmuir theory of adsorption are:

(i) Adsorption takes place on the surface of solid only till the whole of the surface is completely covered with a unimolecular layer of the adsorbed gas.

(ii) Adsorption consists of two opposing processes condensation and evaporation.

(iii) The rate of condensation depend upon the uncovered surface of the adsorbent available for condensation.

9 Langmuir adsorption isotherm is

$$\frac{x}{m} = \frac{ap}{1+bp}$$

At higher pressure, $1 + bp = bp$

$$\frac{x}{m} = \frac{ap}{bp} = \frac{a}{b}$$

10 In Freundlich adsorption isotherm,

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

The value of n is always greater than 1. So, the value of $1/n$ lies between 0 and 1 in all cases.

11 $\frac{x}{m} = p \times T$ is the incorrect relation.

The correct relation is $\frac{x}{m} \propto \frac{p}{T}$.

12 In homogeneous catalysis, reactants and catalyst are in the same phase.

(a) $SO_2(g) + O_2(g) \underset{\text{(Contact process)}}{\overset{\text{Pt}(s)}{\rightleftharpoons}} SO_3(g)$ It is an example of heterogeneous catalysis.

(b) $N_2(g) + H_2(g) \underset{\text{(Haber's process)}}{\overset{\text{Fe}(s)}{\rightleftharpoons}} 2NH_3(g)$ It is an example of heterogeneous catalysis.

(c) $C_{12}H_{22}O_{11}(aq) + H_2O(aq) \overset{\text{HCl }(aq)}{\rightleftharpoons} C_6H_{12}O_6 + C_6H_{12}O_6$

It is an example of homogeneous catalysis.

(d) Oil (l) + $H_2(g) \xrightarrow[\text{Pt }(s)]{\text{(Hardening)}}$ Fat

It is also an example of heterogeneous catalysis.

13 Homogeneous catalysis does not occur at the interface of phases as in case of homogeneous catalysis, reactant and catalyst have same phase and their distribution is uniform throughout.

14 (i) Reaction in which catalyst is in different phase than other (reactants and products) is known as heterogeneous catalysis.

(ii) $2SO_2(g) \xrightarrow{\text{Pt}(s)} 2SO_3(g)$

Here, reactant SO_2 and product SO_3 are in gaseous phase while platinum is in solid phase. So, this reaction represents a heterogeneous catalysis.

(iii) $N_2(g) + 3H_2(g) \xrightarrow{\text{Fe }(s)} 2NH_3(g)$

Similarly, here N_2 and H_2 reactants are in gaseous phase, while Fe is in solid phase. Whereas in other reactions catalyst is in same phase with reactant(s) and product(s).

15 $CO(g) + 2H_2(g) \xrightarrow{\text{Cu, ZnO, }Cr_2O_3(s)} CH_3OH(l)$

In this reaction, reactant and catalyst are in different phase, hence it is an example of heterogeneous catalysis.

16 In heterogeneous catalysis, adsorption lowers the activation energy of the reaction.

17 The efficiency of enzyme catalysis is due to its capacity to lower the activation energy of the reaction. Enzymes are biocatalysts which increases the rate of reaction without being consumed in the reaction. In case of equilibrium reactions, catalysts help in attaining the equilibrium quickly without disturbing the equilibrium.

18 $\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2$

19 Colour of colloidal sol depends upon the size of colloidal gold particles.

20 Most of the enzymes have proteinous nature. They are highly specific and get denaturated by high temperature or UV-rays. At optimum temperature, which is generally in between 25°-35°C, enzyme activity is maximum.

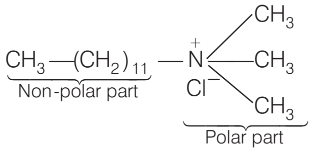
21 Fog is a colloidal solution of liquid in a gas, in which liquid is the dispersed phase whereas gas is the dispersion medium. Examples of other options are as follows:

Gas in liquid : Shaving cream, soda water, froth

Solid in gas : Dust in air

Gas in gas : Atmospheric air.

22 Surfactants detergents form micelles in aqueous solution above their CMC. Dodecyl trimethyl ammonium chloride is an example of surfactant, so it shows a the given phenomenon.



(Dodecyl trimethyl ammonium chloride)

23 Cetyltrimethyl ammonium bromide forms cationic micelles above a certain concentration.

24 Lyophilic colloids are stable due to layer of dispersion medium on the particles.

25 Gold sol is a lyophobic sol, instead of a lyophilic sol. All other given statements are correct.

26 Brownian motion is the random movement of the low weight particles suspended in a fluid. It arises because of the unequal impacts of the particles of the dispersion medium on the colloidal particles.

27 Tyndall effect is more pronounced in hydrophobic sols.

28 Blood may be purified by dialysis.

29 River water is a colloidal solution of clay and sea. Water contains various electrolytes. When river water comes in contact with sea water, then the electrolytes present in sea water coagulate the suspended colloidal particles which ultimately settle down at the point of contact.

30 $Fe(OH)_3$ is a positively charged sol, thus coagulated by negative ion (anion). Smaller the charge on anion, smaller is its coagulating power or higher is its flocculation value.

(a) $KBr \longrightarrow K^+ + Br^-$

(b) $K_2SO_4 \longrightarrow 2K^+ + SO_4^{2-}$

(c) $K_2CrO_4 \longrightarrow 2K^+ + CrO_4^{2-}$

(d) $_4[Fe(CN)_6] \longrightarrow 4K^+ + [Fe(CN)_6]^{4-}$

$\because$ Br^- has smaller charge.

$\therefore$ KBr is least effective in coagulating $Fe(OH)_3$ sol.

31 The process of settling of colloidal particles due to the neutralisation of their charge by any means is called coagulation.

Coagulating power of an ion depends both on **magnitude and sign of the charge** (positive or negative) **on the ion.** This fact can be explained by **Hardy-Schulze rule.**

According to this rule "greater the valency of the coagulating ion/flocculating ion (oppositely charged ion) added, the greater is its power to cause coagulation.

To coagulate a positively charged sol, the order of coagulating power of negative ion is

$$I^- < SO_4^{2-} < PO_4^{3-} < [Fe(CN)_6]^{4-}.$$

Similarly, to coagulate a negatively charged sol, the order of coagulating power of positive ions is

$$Ag^+ < Pb^{2+} < Fe^{3+} < Si^{4+}$$

32 As_2S_3 is a negatively charged sol. Al^{3+} ions from $Al(NO_3)_3$ will be most effective for bringing the coagulation.

33 Negative colloid is coagulated by positive ion or *vice-versa*. Greater the valency of coagulating ion, greater will be coagulating power.

(a) $ZnSO_4 \longrightarrow Zn^{2+} + SO_4^{2-}$

(b) $Na_3PO_4 \longrightarrow 3Na^+ + PO_4^{3-}$

(c) $AlCl_3 \longrightarrow Al^{3+} + 3Cl^-$

(d) $K_4[Fe(CN)_6] \longrightarrow 4K^+ + [Fe(CN)_6]^{4-}$

Since, in $AlCl_3$, the valency of positive ion (coagulating ion) is highest, it is the most powerful coagulating agent among the given to coagulate the negative colloid.

34 As coagulating power is inversely proportional to coagulation value, the ratio of their coagulating powers will be

$$\frac{\text{coagulating power of AlCl}_3}{\text{coagulating power of NaCl}} = \frac{\text{coagulating value of NaCl}}{\text{coagulating value of AlCl}_3} = \frac{52}{0.093}$$

$$= 559 : 1$$

35 Al^{3+} ions coagulate the negative mud particles.

36 Bleeding due to cut can be stopped by applying $FeCl_3$ solution or alum. This is due to coagulation of negatively charged colloidal blood particles (albuminoid substance) by positively charged Fe^{3+} ions. These substances are used as styptic (which check the flow of blood).

37 Lyophobic sols are unstable, so they are stabilised by adding some lyophilic colloids which protect them from precipitation. Thus, lyophilic colloids are called protecting colloids. Their protecting power is expressed in terms of gold number.

Note *Lesser the gold number, higher is the protecting power.*

38 Smaller the value of gold number, greater will be the protecting power of the protective colloid.

Hence, protective nature of *A*, *B* and *C* as

Colloidal solution	*A*	>	*B*	>	*C*
Gold number	0.01		2.5		20

39 Milk is an emulsion in which the particles (or globules) of liquid fats are dispersed in water.

40 The droplets present in emulsion has negative charge. It can be precipitated by adding electrolyte such as KCl, NaCl etc. Since, glucose and urea do not produce ions on dissolving in water.

Hence, they are non-electrolyte and do not precipitate the negatively charged emulsion.

41 Emulsions are liquid-liquid colloidal system. They can't be broken by adding more amount of dispersion medium and adding emulsifying agent, as on adding more amount of dispersion medium they become dilute and on adding emulsifying agent they get stabilises.

SESSION 2

1 Freundlich adsorption isotherm equation is given as

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

On taking log both sides

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

or $$\log\frac{x}{m} = \log 10 + \frac{1}{n}\log 0.5$$

$$\left(\because \text{slope} = \frac{1}{n} = \tan\theta = \tan 45° = 1\right)$$

$$\log\frac{x}{m} = 1 + \frac{1}{1}\log(5 \times 10^{-1})$$

$$\log\frac{x}{m} = 1 + 0.6990 - 1 = 0.6990$$

$$\frac{x}{m} = \text{antilog}\, 0.6990$$

or $$\frac{x}{m} = 5.00\ \text{g}$$

2 Gold number is the number of milligrams of a hydrophilic colloid that will just prevent the coagulation of 10 mL of a gold sol on addition of 1 mL of 10% NaCl solution.

$\therefore$ Gold number $= 0.25 \times 1000 = 250$

3 Volume of the gold dispersed in one litre water

$$= \frac{\text{mass}}{\text{density}} = \frac{1.9 \times 10^{-4}\ \text{g}}{19\ \text{g cm}^{-3}}$$

$$\Rightarrow \quad = 1 \times 10^{-5}\text{cm}^{-3}$$

Radius of gold sol particles $= 10\ \text{nm}$

$$= 10 \times 10^{-9}\ \text{m} = 10 \times 10^{-7}\ \text{cm}$$

$$\Rightarrow \quad = 10^{-6}\ \text{cm}$$

Volume of the gold sol particles $= \frac{4}{3}\pi r^3$

$$= \frac{4}{3} \times \frac{22}{7} \times (10^{-6})^3$$

$$\Rightarrow \quad = 4.19 \times 10^{-18}\ \text{cm}^3$$

Number of gold sol particles in 1×10^{-5} cm^3

$$= \frac{1 \times 10^{-5}}{4.19 \times 10^{-18}}$$

$$\Rightarrow \quad = 2.38 \times 10^{12}$$

Number of gold sol particles in one mm^3

$$= \frac{2.38 \times 10^{12}}{10^6} \Rightarrow \ = 2.38 \times 10^6$$

4 Order of activation energy is $C < B < A$. A catalyst increases the rate of reaction by decreasing activation energy. So, the order of ease of reaction is $C > B > A$.

5 As the adsorption process is exothermic, the physical adsorption occurs readily at low temperature and **decreases** with increasing temperature (in accordance to Le-chatelier's principle, exothermic process favours backward reaction, thus adsorption decreases with increase in temperature). In other words, adsorption **increases** with **decrease** in temperature.

6 A catalyst effect both forward and backward reactions to the same extent in a reversible reaction and thus, helps in the achievement of equilibrium quicker.

Thus, it does not have any effect on spontaniety of a reaction.

7 Extent of adsorption $= kp^{1/n}$ (Freundlich adsorprtion isotherm)

The amount of gas adsorbed does not increase as rapidly as the pressure.

The extent of adsorption $= \dfrac{ap}{(1+bp)}$

(Langmuir - adsorption isotherm)

where, k, a, b are constant and p is pressure.

8 The factors which are responsible for the increase in the rate of surface catalysed reaction are as

(i) A catalyst provides proper orientation for the reactant molecules to react

(ii) Heat of adsorption of reactants on the catalyst, helps reactant molecules to overcome activation energy.

(iii) Adsorption increases the local concentration of reactant molecules on the surface of the catalyst.

9 The reactions which are catalysed by one of the product formed are called auto-catalysis reactions and the product is called auto-catalyst, e.g.

$$2\text{AsH}_3(g) \longrightarrow 2\text{As}(g) + 3\text{H}_2(g)$$

10 $\log \dfrac{x}{m} = \log K + \dfrac{1}{n} \log p$

From $y = mx + c$, slope $\dfrac{1}{n} = \tan 45° = 1$

and $\log K = 0.3010$

$$K = 2$$

$$\log \frac{x}{m} = \log 2 + 1 \log 0.2$$

$$= \log 2 + \log 0.2 = \log 0.4$$

$$\therefore \quad \frac{x}{m} = 0.4$$

11 SnO_2 dissolves in NaOH forming Na_2SnO_3

$$\text{SnO}_2 + 2\text{NaOH} \longrightarrow \text{Na}_2\text{SnO}_3 + \text{H}_2\text{O}$$

SnO_3^{2-} is adsorbed by SnO_2 forming negatively charged colloidal sol.

$$[\text{SnO}_2]\text{SnO}_3^{2-} : 2\text{Na}^+$$

12 Negatively charged colloidal sol is formed when AgNO_3 is completely precipitated as AgI and extra KI is adsorbed on AgI.

$$\text{Ag}^+ + \text{I}^- \longrightarrow \text{AgI}$$

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

Thus, $[\text{Ag}^+] < [\text{I}^-]$

$$\underset{\substack{3\ \text{mol} \\ 1\ \text{mol}}}{3[\text{AgI}]\text{I}^-} + \underset{\substack{1\text{mol} \\ \frac{1}{3}\text{mol}}}{\text{Fe}^{3+}} \longrightarrow 3\text{AgI} + \text{FeI}_3$$

Thus, 1 mol of $[\text{AgI}]\text{I}^-$ is coagulated by the addition of 1 mol of AgNO_3 or 1/2 mol $\text{Pb(NO}_3)_2$ or 1/3 mol of $\text{Fe(NO}_3)_3$.

13 50 mL of 1 M oxalic acid $[(\text{COOH})_2 \cdot 2\text{H}_2\text{O}] = 50$ millimol

$$= 0.050\ \text{mol} = 0.050 \times 126\ \text{g} = 6.3\ \text{g}$$

50 mL of 0.5 M oxalic acid $= 3.15$ g

$\therefore$ Oxalic acid adsorbed on 0.5 g charcoal

$$= 6.3 - 3.15 = 3.15\ \text{g}$$

$\therefore$ Amount of oxalic acid adsorbed per gram of charcoal $= \dfrac{3.19}{0.5} = 6.3\ \text{g}$

14 $\because$ Protective power $\propto \dfrac{1}{\text{gold number}}$

$\therefore$ Order of protective power will be,

Gelatin >	haemoglobin >	sodium acetate
(0.005)	(0.05)	(0.7)

15 Size of colloidal particles = 1 to 1000 nm

$$V_C = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(10)^3$$

Size of true solution particles ≈ 1 nm

$$V_s = \frac{4}{3}\pi(1)^3$$

Thus, $\dfrac{V_C}{V_s} = 10^3$