SURFACE CHEMISTRY

1. INTRODUCTION

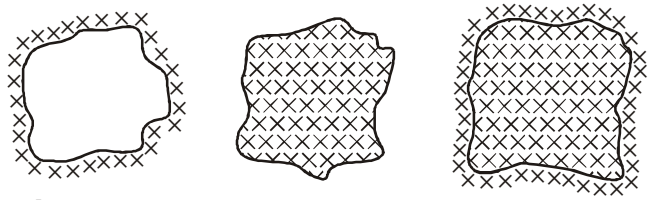
Surface chemistry deals with phenomena that occur at the surfaces or interfaces. The interface or surface is represented by separating the bulk phases by a hyphen or a slash. For example, the interface between a solid and a gas may be represented by solid-gas or solid/gas. Due to complete miscibility, there is no interface between the gases. The bulk phases that we come across in surface chemistry may be pure compounds or solutions. The interface is normally a few molecules thick but its area depends on the size of the particles of bulk phases. Many important phenomena, noticeable amongst these being corrosion, electrode processes, heterogeneous catalysis, dissolution and crystallisation occur at interfaces.

2. ADSORPTION

The tendency of accumulation of molecular species at the surface than in the bulk of a solid (or liquid) is termed **adsorption**. The molecular species or substance which concentrates or accumulates at the surface is termed **adsorbate** and the material on whose surface the adsorption has taken place is called **adsorbent**.

2.1 DISTINCTION BETWEEN ADSORPTION AND ABSORPTION :

In adsorption the concentration of the adsorbate increases only at the surface of the adsorbent, while in absorption the concentration is uniform throughout the bulk of the solid.



Adsorption Absorption Sorption

There are several examples, which reveal that the surface of a solid has the tendency to attract and retain the molecules of the phase with which it comes into contact. These molecules remain only at the surface and do not go deeper into the bulk. Adsorption is essentially a surface phenomenon. Solids, particularly in finely divided state, have large surface area and therefore, charcoal, silica gel, alumina gel, clay, colloids, metals in finely divided state, etc. act as good adsorbents.

(i) In adsorption, the composition of final sample at surface & bulk will differ largely, while in absorption, the composition will be nearly same.

(ii) The rate of adsorption decreases with time but absorption occurs at nearly constant rate.

(iii) Adsorption is always exothermic but absorption may be endothermic or exothermic.

Adsorption in action :

(i) If a gas like O_2, H_2, CO, Cl_2, NH_3 or SO_2 is taken in a closed vessel containing powdered charcoal, it is observed that the pressure of the gas in the enclosed vessel decreases. The gas molecules concentrate at the surface of the charcoal, i.e., gases are adsorbed at the surface.

(ii) In a solution of an organic dye, say methylene blue, when animal charcoal is added and the solution is well shaken, it is observed that the filtrate turns colourless. The molecules of the dye, thus, accumulate on the surface of charcoal, i.e., are adsorbed.

(iii) Aqueous solution of raw sugar, when passed over beds of animal charcoal, becomes colourless as the colouring substances are adsorbed by the charcoal.

(iv) The air becomes dry in the presence of silica gel because the water molecules get adsorbed on the surface of the gel.

In absorption as well as adsorption, the concentration or partial pressure of absorbate or adsorbate, decreases.

Ex. 1. ***A vessel of capacity 8.21L contains NH_3 gas at 1.5 atm and 27°C. Now, 5 gm charcoal is added in the vessel and left for sufficient time. After sufficient time, the pressure of gas decreased to 1.2 atm. Calculate the mass of NH_3 gas adsorbed per gm of charcoal. Neglect the volume of charcoal.***

Sol. *Mass of NH_3 gas adsorbed* $= \frac{\Delta P.V.M.}{RT} = \frac{0.3\times 8.21\times 17}{0.0821\times 300} = 1.7\,gm$

$\therefore$ *Mass of NH_3 gas adsorbed per gm of charcoal* $= \frac{17}{5} = 0.34\,gm$

2.2 MECHANISM OF ADSORPTION :

Adsorption is due to the fact that the surface particles of the adsorbent are in different state than the particles inside the bulk.

(i) Inside the adsorbent all the force acting between the particles are mutually balanced but on the surface the particles are not surrounded by atoms or molecules of their kind on all sides and hence they possess **Unbalanced or residual attractive force**. These forces of the adsorbent are responsible for attracting the adsorbate particle on its surface.

(ii) Another important factor featuring adsorption is the heat of adsorption. During adsorption, there is always a decrease in residual forces of the surface, i.e., there is decrease in surface energy which appears as heat. Adsorption, therefore, is invariably an exothermic process. In other words, ΔH of adsorption is always negative. When a gas is adsorbed, the freedom of movement of its molecules become restricted. This amounts to decrease in the entropy of the gas after adsorption, i.e., ΔS is negative. Adsorption is thus accompanied by decrease in enthalpy as well as decrease in entropy of the system. For a process to be spontaneous, the thermodynamic requirement is that, at constant temperature and pressure, ΔG must be negative, i.e., there is a decrease in Gibbs energy. On the basis of equation, $\Delta G = \Delta H - T\Delta S$, ΔG can be negative if ΔH has sufficiently high negative value as $-T\Delta S$ is positive. Thus, in an adsorption process, which is spontaneous, a combination of these two factors makes ΔG negative. As the adsorption proceeds, ΔH becomes less and less negative ultimately ΔH becomes equal to $T\Delta S$ and ΔG becomes zero. At this state equilibrium is attained.

The adsrobate particles may undergo the following further activity :

(i) If nature & condition will favour, they will diffuse in bulk resulting in adsorption.

(ii) They may move at the surface.

(iii) They come out of the surface resulting desorption.

Normally, desorption follows I order kinetics & obeys Arrehenius equation.

Ex.2. ***Calculate the time upto which a hydrogen molecule may remain absorbed at pt surface at 500 K. ($A = 14 \times 10^{15}$ sec^{-1}, $E_a = 10$ kcal/mole)***

Sol. $T_{av} = \dfrac{1}{1.4\times10^{15}\ e^{-10}} = \dfrac{e^{10}}{1.4\times10^{15}}$

2.3 TYPES OF ADSORPTION :

There are two main types of adsorption of gases on solids.

(i) Physical adsorption or physisorption :

In this adsorption, accumulation of gas on the surface of a solid occurs on account of weak VanderWaals' force.

(ii) Chemical adsorption or chemisorption.

The gas molecules or atoms are held to the solid surface by chemical bonds (covalent or ionic) in nature. Chemisorption has high energy of activation and is, therefore, often referred as **activated adsorption**.

Sometimes these two processes occur simultaneously and it is not easy to ascertain the type of adsorption.

Note :

A physical adsorption at low temperature may pass into chemisorption as the temperature is increased. For example, hydrogen is first adsorbed on nickel by van der Waals' force. Molecules of hydrogen then dissociate and hydrogen atoms are held on the surface by chemisorption.

COMPARISON OF CHARACTERSTICS OF PHYSISORPTION AND CHEMISORPTION

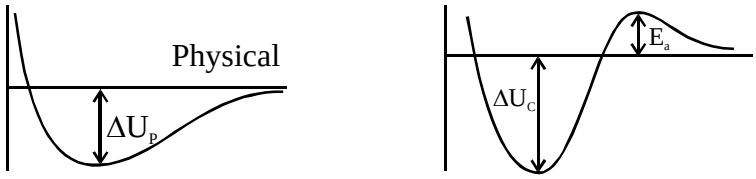
	PHYSICAL ADSORPTION	CHEMICAL ADSORPTION
1	It is caused by weak forces.	It is caused by chemical bond formation
2	It is not specific.	It is highly specific (Bond formation is necessary)
3	It is reversible.	It is irreversible.
4	It depends on the nature of gas. More easily liquefiable gases are adsorbed readily.	It depends on the nature of gas. Gases which form compounds with the adsorbent exhibit chemi-sorption.
5	Enthalpy of adsorption is low (20-40 kJ mol^{-1})	Enthalpy of adsorption is low (80-240 kJ mol^{-1})
6	Low temperature is favourable. It decreases with increase of temperature.	High temperature is favourable. It increases with the increase in temperature upto certain limit.
7	No appreciable activation energy is involved.	High activation energy is involved.
8	High pressure is favourable. Decrease of pressure causes desorption.	High pressure is favourable. Decrease of pressure does not cause desorption.
9	It forms multilayers on adsorbent surface under high pressure.	It forms unimolecular layer.

Note :

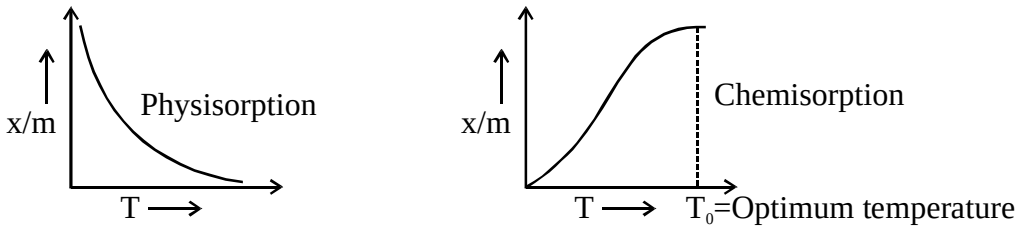
(i) Chemisorption is irreversible. Either desorption does not occur or molecules other than adsorbate leave the surface.

(ii) Chemisorption is more exothermic & hence its E_a should be negligible. But in reality it is high due to requirement of bond cleavage in the adsorbate molecule before adsorption.
Due to higher E_a, it is called **activated adsorption**.

(iii)



(iv) On increasing temperature, the extent of physisorption decreases but chemisorption increases.



x : mass of adsorbate

and m : mass of adsorbent

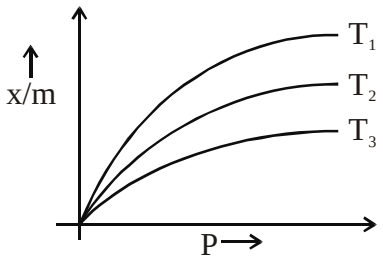
2.4 FACTORS AFFECTING ADSORPTION OF GASES ON SOLIDS :

(i) Nature of gas : Easily liquifiable gases (having higher critical temperature) adsorb to the greater extent.

(ii) Nature of adsorbent : Specific surface area represent the surface area of adsorbent per unit mass. Greater the specific surface area, more will be the adsorption. Charcoal, silica gel, alumina gel, colloids are good adsorbents.

(iii) Surface area : Adsorption increases on increasing the surface area.

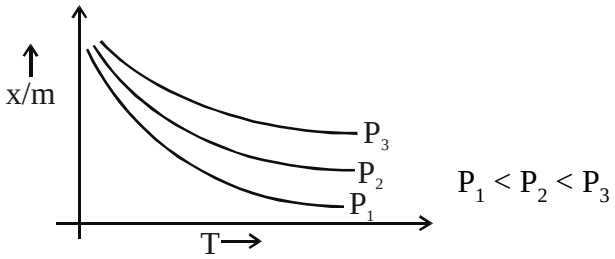
(iv) Pressure : Adsorption of gas at solid surface (increases due to) decrease in volume of system & hence extent of adsorption increases on increasing pressure.



$T_1 < T_2 < T_3$

Adsorption isotherms

(v) Temperature : T↑ Physisorption ↓ Chemisorption ↑



Adsorption isobars

2.4.1 Freundlich adsorption isotherm :

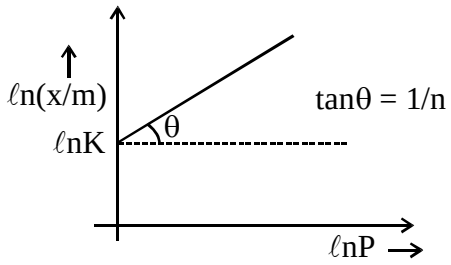
Freundlich, in 1909, gave an empirical relationship between the quantity of gas adsorbed (x) by unit mass of solid adsorbent (m) and pressure at a particular temperature. The relationship can be expressed by the following equation.

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

where K & n are constant, depending on nature of gas, solid & temperature.

For any combination of gas, solid & temperature, the values of k & n may be determined graphically.

$$\ell n\left(\frac{x}{m}\right) = \ell nK + \frac{1}{n}\ell nP$$



Freundlich isotherm is straight line. Freundlich isotherm fails at high pressure.

2.4.2 Langmuir's adsorption isotherm :

He derived the condition of equilibrium theoretically assuming that adsorbtion is

(a) monolayer

(b) uniform at solid surface

(c) adsorbate particles do not interact each other at the surface.

$$M(s) + X(g) \underset{\text{desoprtion}}{\overset{\text{adsorbtion}}{\rightleftharpoons}} M - X(s)$$

At any instant :

Rate of adsorption, $r_a \propto P$

$$\propto (1-\theta)$$

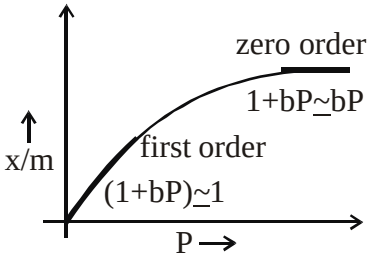
$$\therefore \quad r_a = K_a P(1-\theta)$$

where, θ = Fraction of surface area already occupied by adsorbate particles.

and Rate of desorption, $r_d \propto \theta \quad \Rightarrow \quad r_d = K_d.\theta$

At eqb. $r_a = r_d$

$$\theta = \frac{K_aP}{K_d + K_aP} = \frac{K_a/K_d\,P}{1 + K_a/K_d\,P} = \frac{K_{eq}P}{1+K_{eq}P}$$



Now, $\frac{x}{m} \propto \theta$

$$\frac{x}{m} = K\theta = K\frac{K_{eq.}P}{1+K_{eq.}P} = \frac{aP}{1+b.P}$$

a, b = constant

2.5 ADSORPTION FROM SOLUTION PHASE :

Solids can adsorb solutes from solutions also. When a solution of acetic acid in water is shaken with charcoal, a part of the acid is adsorbed by the charcoal and the concentration of the acid decreases in the solution. Similarly, the litmus solution when shaken with charcoal becomes colourless. The precipitate of $Mg(OH)_2$ attains blue colour when precipitated in presence of magneson reagent. The colour is due to adsorption of magneson. The following observations have been made in the case of adsorption from solution phase:

(i) The extent of adsorption decreases with an increase in temperature.

(ii) The extent of adsorption increases with an increase of surface area of the adsorbent.

(iii) The extent of adsorption depends on the concentration of the solute in solution.

(iv) The extent of adsorption depends on the nature of the adsorbent and the adsorbate.

The precise mechanism of adsorption from solution is not known. Freundlich's equation approximately describes the behaviour of adsorption from solution with a difference that instead of pressure, concentration of the solution is taken into account, i.e.,

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

(C is the equilibrium concentration, i.e., when adsorption is complete).

On taking logarithm of the above equation, we have

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

Plotting $\log\frac{x}{m}$ against $\log C$ a straight line is obtained which shows the validity of Freundlich isotherm.

This can be tested experimentally by taking solutions of different concentrations of acetic acid. Equal volumes of solutions are added to equal amounts of charcoal in different flasks. The final concentration is determined in each flask after adsorption. The difference in the initial and final concentrations give the value of x. Using the above equation, validity of Freundlich isotherm can be established.

2.6 APPLICATIONS OF ADSORPTION :

The phenomenon of adsorption finds a number of applications. Important ones are listed here:

(i) Production of high vacuum :

The remaining traces of air can be adsorbed by charcoal from a vessel evacuated by a vacuum pump to give a very high vacuum.

(ii) Gas masks:

Gas mask (a device which consists of activated charcoal or mixture of adsorbents) is usually used for breathing in coal mines to adsorb poisonous gases.

(iii) Control of humidity:

Silica and aluminium gels are used as adsorbents for removing moisture and controlling humidity.

(iv) Removal of colouring matter from solutions:

Animal charcoal removes colours of solutions by adsorbing coloured impurities.

(v) Heterogeneous catalysis:

Adsorption of reactants on the solid surface of the catalysts increases the rate of reaction. There are many gaseous reactions of industrial importance involving solid catalysts. Manufacture of ammonia using iron as a catalyst, manufacture of H_2SO_4 by contact process and use of finely divided nickel in the hydrogenation of oils are excellent examples of heterogeneous catalysis.

(vi) Separation of inert gases:

Due to the difference in degree of adsorption of gases by charcoal, a mixture of noble gases can be separated by adsorption on coconut charcoal at different temperatures.

(vii) In curing diseases: A number of drugs are used to kill germs by getting adsorbed on them.

(viii) Froth floatation process:

A low grade sulphide ore is concentrated by separating it from silica and other earthy matter by this method using pine oil and frothing agent

(ix) Adsorption indicators:

Surfaces of certain precipitates such as silver halides have the property of adsorbing some dyes like eosin, fluorescein, etc. and thereby producing a characteristic colour at the end point.

(x) Chromatographic analysis:

Chromatographic analysis based on the phenomenon of adsorption finds a number of applications in analytical and industrial fields.

3. CATALYSIS

The systematic study of the effect of various foreign substances on the rates of chemical reactions was first made by Berzelius, in 1835. He suggested the term catalyst for such substances. Substances, which accelerate the rate of a chemical reaction and themselves remain chemically and quantitatively unchanged after the reaction, are known as catalysts, and the phenomenon is known as catalysis.

3.1 HOMOGENEOUS AND HETERGENEOUS CATALYSIS :

Catalysis can be broadly divided into two groups:

(a) Homogeneous catalysis :

When the reactants and the catalyst are in the same phase (i.e., liquid or gas), the process is said to be homogeneous catalysis. The following are some of the examples of homogeneous catalysis:

(i) Oxidation of sulphur dioxide into sulphur trioxide with dioxygen in the presence of oxides of nitrogen as the catalyst in the lead chamber process.

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

The reactants, sulphur dioxide and oxygen, and the catalyst, nitric oxide, are all in the same phase.

(ii) Hydrolysis of methyl acetate is catalysed by H+ ions furnished by hydrochloric acid.

$$CH_3COOCH_3(l) + H_2O(l) \xrightarrow{HCl(l)} CH_3COOH(aq) + CH_3OH(aq)$$

Both the reactants and the catalyst are in the same phase.

3.2 HETEROGENEOUS CATALYSIS :

The catalytic process in which the reactants and the catalyst are in different phases is known as heterogeneous catalysis. Some of the examples of heterogeneous catalysis are given below:

(i) Oxidation of sulphur dioxide into sulphur trioxide in the presence of Pt.

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

The reactant is in gaseous state while the catalyst is in the solid state.

(ii) Combination between dinitrogen and dihydrogen to form ammonia in the presence of finely divided iron in Haber's process.

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

The reactants are in gaseous state while the catalyst is in the solid state.

(iii) Oxidation of ammonia into nitric oxide in the presence of platinum gauze in Ostwald's process.

$$4NH_3(g) + 5O_2(g) \xrightarrow{Pt(s)} 4NO(g) + 6H_2O(g)$$

The reactants are in gaseous state while the catalyst is in the solid state

Adsorption Theory of Heterogeneous Catalysis :

This theory explains the mechanism of heterogeneous catalysis. The old theory, known as adsorption theory of catalysis, was that the reactants in gaseous state or in solutions, are adsorbed on the surface of the solid catalyst. The increase in concentration of the reactants on the surface increases the rate of reaction. Adsorption being an exothermic process, the heat of adsorption is utilised in enhancing the rate of the reaction. The modern adsorption theory is the combination of intermediate compound formation theory and the old adsorption theory. The catalytic activity is localised on the surface of the catalyst. The mechanism involves five steps:

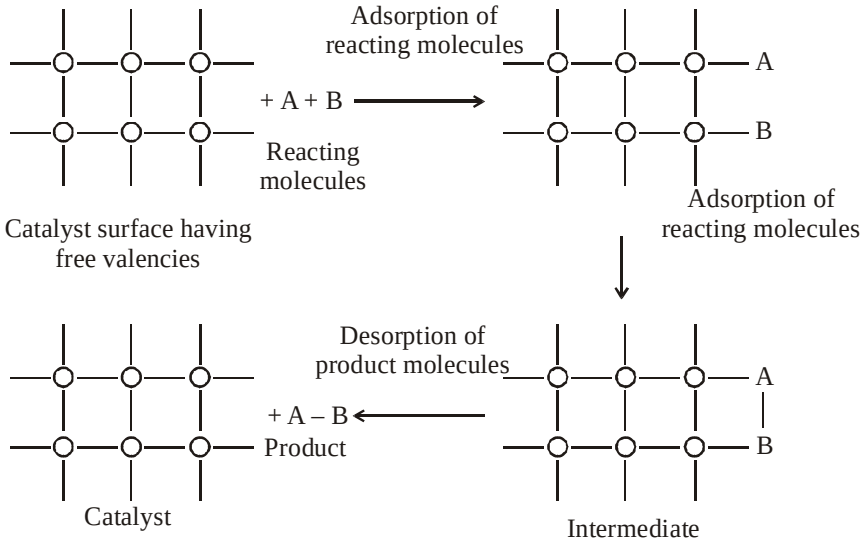
(i) Diffusion of reactants to the surface of the catalyst.

(ii) Adsorption of reactant molecules on the surface of the catalyst.

(iii) Occurrence of chemical reaction on the catalyst's surface through formation of an intermediate

(iv) Desorption of reaction products from the catalyst surface, and thereby, making the surface available again for more reaction to occur.

(v) Diffusion of reaction products away from the catalyst's surface. The surface of the catalyst unlike the inner part of the bulk, has free valencies which provide the seat for chemical forces of attraction. When a gas comes in contact with such a surface, its molecules are held up there due to loose chemical combination. If different molecules are adsorbed side by side, they may react with each other resulting in the formation of new molecules. Thus, formed molecules may evaporate leaving the surface for the fresh reactant molecules. This theory explains why the catalyst remains unchanged in mass and chemical composition at the end of the reaction and is effective even in small quantities. It however, does not explain the action of catalytic promoters and catalytic poisons.



Adsorption of reacting molecules, formation of intermediate and desorption of products

3.3 IMPORTANT FEATURES OF SOLID CATALYSTS :

(a) Activity :

The activity of a catalyst depends upon the strength of chemisorption to a large extent. The reactants must get adsorbed reasonably strongly on to the catalyst to become active. However, they must not get adsorbed so strongly that they are immobilised and other reactants are left with no space on the catalyst's surface for adsorption. It has been found that for hydrogenation reaction, the catalytic activity increases from Group 5 to Group 11 metals with maximum activity being shown by groups 7-9 elements of the periodic table

$$2H_2(g) + O_2(g) \xrightarrow{Pt} 2H_2O(I)$$

(b) Selectivity :

The selectivity of a catalyst is its ability to direct a reaction to yield a particular product. For example, starting with H_2 and CO, and using different catalysts, we get different products.

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

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

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

Thus, it can be inferred that the action of a catalyst is highly selective in nature, i.e., a given substance can act as a catalyst only in a particular reaction and not for all the reactions.

3.4 SHAPE-SELECTIVE CATALYSIS BY ZEOLITES :

The catalytic reaction that depends upon the pore structure of the catalyst and the size of the reactant and product molecules is called shape-selective catalysis. Zeolites are good shape-selective catalysts because of their honeycomb-like structures. They are microporous aluminosilicates with three dimensional network of silicates in which some silicon atoms are replaced by aluminium atoms giving Al–O–Si framework. The reactions taking place in zeolites depend upon the size and shape of reactant and product molecules as well as upon the pores and cavities of the zeolites.

They are found in nature as well as synthesised for catalytic selectivity. Zeolites are being very widely used as catalysts in petrochemical industries for cracking of hydrocarbons and isomerisation. An important zeolite catalyst used in the petroleum industry is ZSM-5. It converts alcohols directly into gasoline (petrol) by dehydrating them to give a mixture of hydrocarbons.

3.5 ENZYME CATALYSIS :

Enzymes are complex nitrogenous organic compounds which are produced by living plants and animals. They are actually protein molecules of high molecular mass and form colloidal solutions in water. They are very effective catalysts, numerous reactions that occur in the bodies of animals and plants to maintain the life process are catalysed by enzymes. The enzymes are, thus, termed as **biochemical catalysts** and the phenomenon is known as **biochemical catalysis**. Many enzymes have been obtained in pure crystalline state from living cells. However, the first enzyme was synthesised in the laboratory in 1969. The following are some of the examples of enzyme-catalysed reactions:

(i) Inversion of cane sugar: The invertase enzyme converts cane sugar into glucose and fructose.

$$\underset{\text{Cane Sugar}}{C_{12}H_{22}O_{11}(aq)} + H_2O(I) \xrightarrow{\text{Invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{Fructose}}{C_6H_{12}O_6(aq)}$$

(ii) Conversion of glucose into ethyl alcohol: The zymase enzyme converts glucose into ethyl alcohol and carbon dioxide.

$$\underset{\text{Glucose}}{C_6H_{12}O_6(aq)} \xrightarrow{\text{Zymase}} 2\underset{\text{Ethyl alcohol}}{C_2H_5OH(aq)} + 2CO_2(g)$$

(iii) Conversion of starch into maltose: The diastase enzyme converts starch into maltose.

$$2\underset{\text{Starch}}{(C_6H_{10}O_5)_n(aq)} + nH_2O(I) \xrightarrow{\text{Diastase}} n\underset{\text{Maltose}}{C_{12}H_{22}O_{11}(aq)}$$

(iv) Conversion of maltose into glucose: The maltase enzyme converts maltose into glucose.

$$\underset{\text{Maltose}}{C_{12}H_{22}O_{11}(aq)} + H_2O(I) \xrightarrow{\text{Maltase}} 2\underset{\text{Glucose}}{C_6H_{12}O_6(aq)}$$

(v) Decomposition of urea into ammonia and carbon dioxide: The enzyme urease catalyses this decomposition.

$$NH_2CONH_2(aq) + H_2O(I) \xrightarrow{\text{Urease}} 2NH_3(g) + CO_2(g)$$

(vi) In stomach, the pepsin enzyme converts proteins into peptides while in intestine, the pancreatic trypsin converts proteins into amino acids by hydrolysis.

(vii) Conversion of milk into curd: It is an enzymatic reaction brought about by lacto bacilli enzyme present in curd.

3.5.1 Characteristics of enzyme catalysis :

Enzyme catalysis is unique in its efficiency and high degree of specificity. The following characteristics are exhibited by enzyme catalysts:

(i) Most highly efficient: One molecule of an enzyme may transform one million molecules of the reactant per minute.

(ii) Highly specific nature: Each enzyme is specific for a given reaction, i.e., one catalyst cannot catalyse more than one reaction. For example, the enzyme urease catalyses the hydrolysis of urea only. It does not catalyse hydrolysis of any other amide.

(iii) Highly active under optimum temperature: The rate of an enzyme reaction becomes maximum at a definite temperature, called the optimum temperature. On either side of the optimum temperature, the enzyme activity decreases. The optimum temperature range for enzymatic activity is 298-310K. Human body temperature being 310 K is suited for enzyme-catalysed reactions.

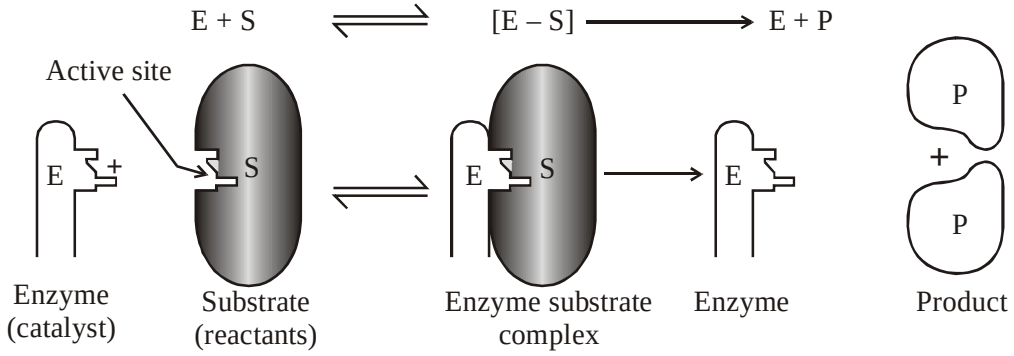
(iv) Highly active under optimum pH: The rate of an enzyme-catalysed reaction is maximum at a particular pH called optimum pH, which is between pH values 5-7.

(v) Increasing activity in presence of activators and co-enzymes: The enzymatic activity is increased in the presence of certain substances, known as co-enzymes. It has been observed that when a small non-protein (vitamin) is present along with an enzyme, the catalytic activity is enhanced considerably. Activators are generally metal ions such as Na^+, Mn^{2+}, CO^{2+}, Cu^{2+}, etc. These metal ions, when weakly bonded to enzyme molecules, increase their catalytic activity. Amylase in presence of sodium chloride i.e., Na^+ ions are catalytically very active.

(vi) Influence of inhibitors and poisons: Like ordinary catalysts, enzymes are also inhibited or poisoned by the presence of certain substances. The inhibitors or poisons interact with the active functional groups on the enzyme surface and often reduce or completely destroy the catalytic activity of the enzymes. The use of many drugs is related to their action as enzyme inhibitors in the body.

3.5.2 Mechanism of enzyme catalysis :

There are a number of cavities present on the surface of colloidal particles of enzymes. These cavities are of characteristic shape and possess active groups such as $–NH_2$, –COOH, –SH, –OH, etc. These are actually the active centres on the surface of enzyme particles. The molecules of the reactant (substrate), which have complementary shape, fit into these cavities just like a key fits into a lock. On account of the presence of active groups, an activated complex is formed which then decomposes to yield the products. Thus, the enzyme-catalysed reactions may be considered to proceed in two steps.



3.5.3 Mechanism of enzyme catalysed reaction :

Step 1: Binding of enzyme to substrate to form an activated complex.

$$E + S \rightleftharpoons ES^*$$

Step 2: Decomposition of the activated complex to form product.

$$ES^* \rightarrow E + P$$

3.6 CATALYTIC PROMOTORS :

There are the substances, which are not the catalyst of that reaction but increases the activity of catalyst.

$N_2 + 3H_2 \longrightarrow 2NH_3$; rate = r_1

$N_2 + 3H_2 \xrightarrow{Fe} 2NH_3$; rate = r_2

$N_2 + 3H_2 \xrightarrow{Mo} 2NH_3$; rate = r_3

$N_2 + 3H_2 \xrightarrow{Fe-Mo} 2NH_3$; rate = r_4

Experimentally, $r_1 = r_3 < r_2 < r_4$. It suggests that Mo is not catalyst of this reaction. But when it is mixed with iron, it increased the catalytic activity of iron. Hence, Mo is catalytic promotor in this reaction.

3.7 CATALYTIC POISONS :

These are the substances, which are not the catalyst of that reaction but decreases the activity of catalyst.

$N_2 + 3H_2 \xrightarrow[H_2S]{\text{Fe with}} 2NH_3$, rate = r_5

$N_2 + 3H_2 \xrightarrow{H_2S} 2NH_3$, rate = r_6

Experimentally, $r_1 = r_6 < r_5 < r_2$. It suggests that H_2S is not catalyst of reaction but it decreases the activity of Fe catalyst. Hence, H_2S is catalytic poison is this reaction.

3.8 AUTO CATALYSIS :

These are the reactions in which some of the product of reaction, catalyses the reaction.

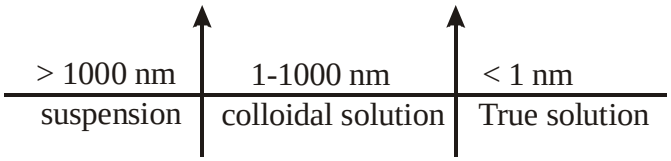
For example

$$RCOOR' + H_2O \longrightarrow \underset{\text{catalyst}}{RCOOH} + R'OH$$

4. COLLOIDS

A colloid is a heterogeneous system in which one substance is dispersed (dispersed phase) as very fine particles in another substance called dispersion medium.

4.1 PARTICLE SIZE :



4.2 PHASE OF COLLOIDS :

A colloidal system is heterogeneous in character. It consists of two phases, namely a dispersed phase and a dispersion medium.

(a) Dispersed Phase : It is the component present in small proportion and is just like a solute in a true solution. For example, in the colloidal state of sulphur in water, the former acts as a dispersed phase.

(b) **Dispersion Medium :** It is normally the component present in excess and is just like a solvent in a solution.

The particles of the dispersed phase are scattered in the dispersion medium in a colloidal system.

4.3 CLASSIFICATION OF COLLOIDS :

Colloids can be can be classified in a number of ways based upon some of their important characteristics.

4.3.1 Physical state of Dispersed Phase & Dispersion Medium:

Depending upon whether the dispersed phase and the dispersion medium are solids, liquids or gaseous, eight types of colloidal system are possible.

A gas mixed with another gas forms a homogeneous mixture and not a colloidal system. Typical examples of various type alongwith their characteristic names are given in table.

Types of Colloidal Systems

Dispersed phase	Dispersion medium	Type of colloid	Examples
Solid	Solid	Solid sol	Some coloured glasses and gem stones
Solid	Liquid	Sol	Paints, cell fluids
Solid	Gas	Aerosol	Smoke, dust
Liquid	Solid	Gel	Cheese, butter, jellies
Liquid	Liquid	Emulsion	Milk, hair cream
Liquid	Gas	Aerosol	Fog, mist, cloud, insecticide sprays
Gas	Solid	Solid sol	Pumice stone, foam rubber.
Gas	Liquid	Foam	Froth, whipped cream, soap lather

* A colloidal system in which the dispersion medium is a liquid or gas are called sols. They are called hydrosols or aqua sols, if the dispersion medium is water. When the dispersion medium is alcohol or benzene , they are accordingly called alcosols or benzosol.

* Colloidal systems in which the dispersion medium is a gas are called aerosols.
* Colloids in which the dispersion medium is a solid are called gels, e.g. cheese etc. They have a more rigid structure. Some colloids, such as gelatin, can behave both as a sol and a gel. At high temperature and low concentration of gelatin, the colloid is a hydrosol. But at low temperature and high gelatin concentration, the hydrosol can change into a gel.

4.3.2 Based on interaction or affinity of phases : On the basis of the affinity or interaction between the dispersed phase and the dispersion medium, the colloids may be classified into two types :

(i) Lyophilic colloids : The word 'lyophilic' means liquid-loving. Colloidal sols directly formed by mixing substances like gum, gelatine, starch, rubber, etc., with a suitable liquid (the dispersion medium) are called lyophilic sols. An important characteristic of these sols is that if the dispersion medium is separated from the dispersed phase (say by evaporation), the sol can be reconstituted by simply remixing with the dispersion medium. That is why these sols are also called reversible sols. Which are quite stable.

(ii) Lyophobic colloids : The word 'lyophobic' means liquid-hating. Substances like metals, their sulphides, etc., when simply mixed with the dispersion medium do not form the colloidal sol. Their colloidal sols can be prepared only by special methods. Such sols are called lyophobic sols. These sols are readily precipitated (or coagulated) on the addition of small amounts of electrolytes, by heating or by shaking and hence, are not stable. Further, once precipitated, they do not give back the colloidal sol by simple addition of the dispersion medium. Hence, these sols are also called irreversible sols. Lyophobic sols need stabilising agents for their preservation.

Difference between Lyophilic and Lyophobic sols

Property	Lyophilic sols	Lyophobic sols
1. Nature	Reversible	Irreversible
2. Preparation	They are prepared very easily by shaking or warming the substance with dispersion medium. They do not required any electrolyte for stabilization.	They are difficult to prepare, Special methods are used. Addition of stabiliser is essential for their stability.
3. Stability	They are very stable and are not easily coagulated by electrolytes.	They are generally unstable and get easily coagulated on addition of electrolytes.
4. Charge	Particles carry no or very little charge depending upon the pH of the medium.	Colloidal particles have characteristic charge (positive or negative)
5. Viscosity	Viscosity is much higher than that of the medium.	Viscosity is nearly the same as that of the medium
6. Migration in electric field	The particles may or may not migrate in an electric field.	The colloidal particles migrate either towards cathode or anode in an electric field.
7. Solvation	Particles are heavily solvated.	Particles are not solvated.
8. Action of electrolyte	Large amount of electrolyte is required to cause coagulation.	Small amount of electrolyte is sufficient to cause cogulation.
9. Examples	Mostly organic substances e.g. starch, gums, proteins, gelatin etc.	Generally inorganic substance e.g., metal sols, sulphides and oxides sols.

4.3.3 Classification Based on Type of Particles of the Dispersed Phase :

Depending upon the type of the particles of the dispersed phase, colloids are classified as: multimolecular, macromolecular and associated colloids.

(i) **Multimolecular colloids:** On dissolution, a large number of atoms or smaller molecules of a substance aggregate together to form species having size in the colloidal range (diameter<1nm). The species thus formed are called multimolecular colloids. For example, a gold sol may contain particles of various sizes having many atoms. Sulphur sol consists of particles containing a thousand or more of S8 sulphur molecules.

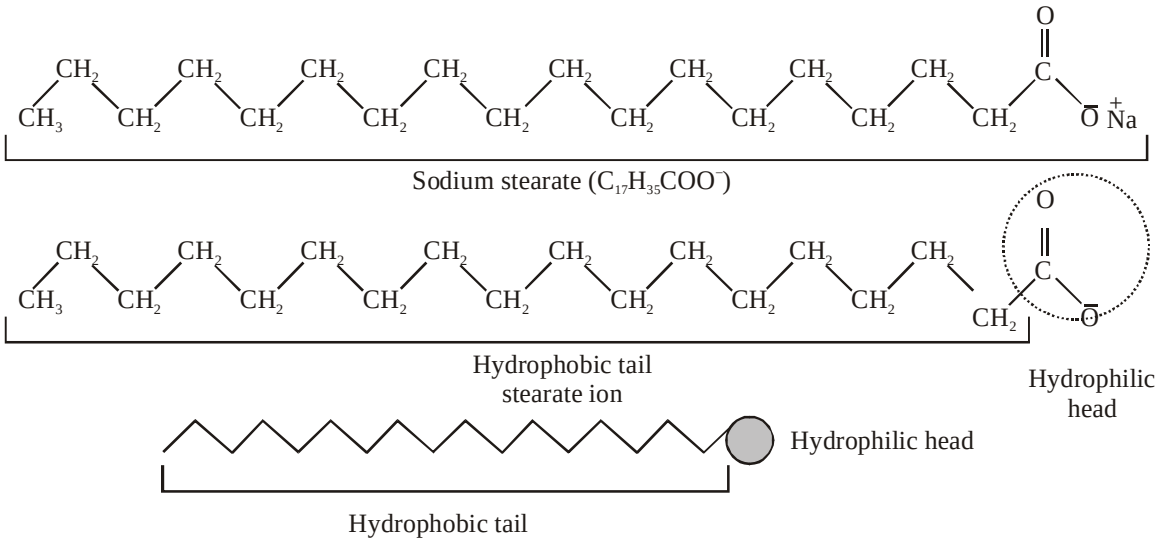
(ii) **Macromolecular colloids:** Macromolecules (Unit 15) in suitable solvents form solutions in which the size of the macromolecules may be in the colloidal range. Such systems are called macromolecular colloids. These colloids are quite stable and resemble true solutions in many respects. Examples of naturally occurring macromolecules are starch, cellulose, proteins and enzymes; and those of man-made macromolecules are polythene, nylon, polystyrene, synthetic rubber, etc.

(iii) **Associated colloids (Micelles):** There are some substances which at low concentrations behave as normal strong electrolytes, but at higher concentrations exhibit colloidal behaviour due to the formation of aggregates. The aggregated particles thus formed are called micelles. These are also known as associated colloids.

The formation of micelles takes place only above a particular temperature called **Kraft temperature** (Tk) and above a particular concentration called **critical micelle concentration** (CMC). On dilution, these colloids revert back to individual ions. Surface active agents such as soaps and synthetic detergents belong to this class. These colloids have both lyophobic and lyophilic parts. Micelles may contain as many as 100 molecules or more.

Mechanism of micelle formation :

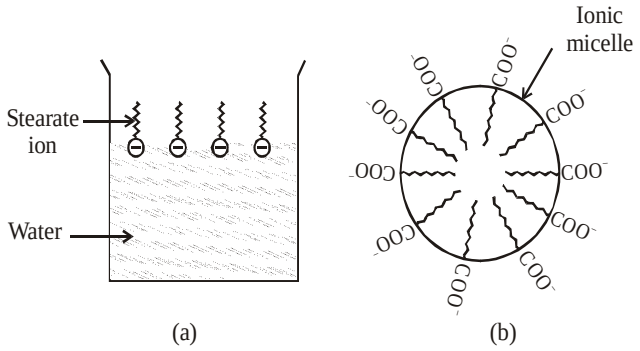
Let us take the example of soap solutions. Soap is sodium or potassium salt of a higher fatty acid and may be represented as $RCOO^-Na^+$ (e.g., sodium stearate $CH_3(CH_2)_{16}COO^-Na^+$, which is a major component of many bar soaps). When dissolved in water, it dissociates into RCOO– and Na+ ions. The $RCOO^-$ ions, however, consist of two parts — a long hydrocarbon chain R (also called non-polar 'tail') which is hydrophobic (water repelling), and a polar group COO^- (also called polar-ionic 'head'), which is hydrophilic (water loving).



Hydrophobic and hydrophilic parts of stearate ion

The $RCOO^-$ ions are, therefore, present on the surface with their COO^- groups in water and the hydrocarbon chains R staying away from it and remain at the surface. But at critical micelle concentration, the anions are pulled into the bulk of the solution and aggregate to form a spherical shape with their hydrocarbon chains pointing towards the centre of the sphere with COO^- part remaining outward on the surface of the sphere. An aggregate thus formed is known as 'ionic micelle'. These micelles may contain as many as 100 such ions.

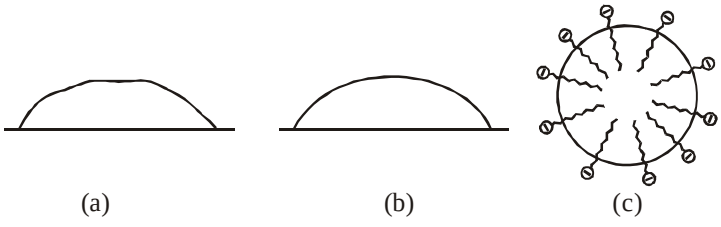
Similarly, in case of detergents, e.g., sodium laurylsulphate, $CH_3(CH_2)_{11}SO_4^-\ Na^+$, the polar group is $-SO_4-$ along with the long hydrocarbon chain. Hence, the mechanism of micelle formation here also is same as that of soaps.



(a) Arrangement of stearate ions on the surface of water at law concentration of soap
(b) Arrangement of stearate ions inside the bulk of water (ionic micelle) at critical micelle concentration of soap

Cleansing action of soaps :

It has been mentioned earlier that a micelle consists of a hydrophobic hydrocarbon – like central core. The cleansing action of soap is due to the fact that soap molecules form micelle around the oil droplet in such a way that hydrophobic part of the stearate ions is in the oil droplet and hydrophilic part projects out of the grease droplet like the bristles. Since the polar groups can interact with water, the oil droplet surrounded by stearate ions is now pulled in water and removed from the dirty surface.The negatively charged sheath around the globules prevents them from coming together and forming aggregates.



(a) Grease on cloth (b) Stearate ions arranging around the grease droplet and
(c) Grease droplet surrounded by stearate ions (micelle formed)

LIST OF SURFACTANTS AND THEIR CRITICAL MICELLE CONCENTRATION (CMC)

Surfactant	CMC (g/1)	Temp.(°C)
Anionic		
$CH_3(CH_2)_6COONa$	6.5×10^1	20
$CH_3(CH_2)_{10}COONa$	5.6	20–70
$CH_3(CH_2)_7OSO_3Na$	3.0×10^1	25–50
$CH_3(CH_2)_{11}OSO_3Na$	2.6	25–60
$CH_3(CH_2)_5C_6H_4SO_3Na$	9.8	75
$CH_3(CH_2)_{11}C_6H_4SO_3Na$	4.0×10^{-1}	50–75
Cationic		
$CH_3(CH_2)_9NH_2.HCl$	8.5	25
$CH_3(CH_2)_{11}NH_2HCl$	2.7	30–50
$CH_3(CH_2)_7N(CH_3)_3Br$	7.8×10^1	25
$CH_3(CH_2)_{11}N(CH_3)_3Br$	5.4	25
Non-ionic		
$CH_3(CH_2)_7C_6H_{11}O_6$	7.3	25
$C_{12}H_{20}O_9(C_{16}H_{31}O_2)_2$	$1.1. \times 10^{-2}$	20
$CH_3(CH_2)_{10}COOC_{12}H_{21}O_{10}$	7.1×10^{-3}	50

4.4 PREPARATION OF COLLOIDAL SOLUTIONS :

(1) Preparation of lyophilic sols : The colloidal solutions of lyophilic colloids like starch, glue, gelatin etc., can be readily prepared by dissolving these substances in water either by cooling or warming. Solutions of colloidal electrolytes such as soaps and dye stuffs can also be prepared similarly.

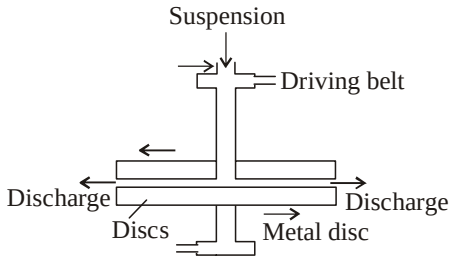
(2) Preparation of lyophobic sols : To get a substance in colloidal form either the substance in bulk is broken down into fine particles of colloidal dimension (1Å to 10^3 Å) or increasing the size of molecular particles as to form larger aggregates. In some cases, a third substance as to form larger aggregates. In some cases, a third substance is usually added to increase the stability of the sol. These substances are called stabilizers. Thus, there are two ways by which the lyophobic sols can be prepared :

(i) Dispersion methods : By splitting coarse aggregates of a substance into colloidal size.

(ii) Condensation methods : By aggregating very small particles (atoms, ions or molecules) into colloidal size.

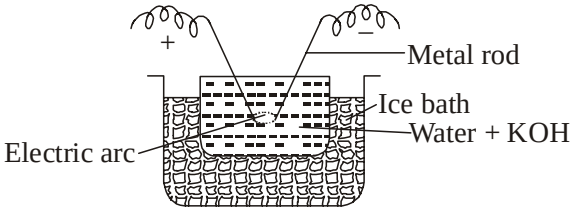
(i) Dispersion Methods :

(A) Mechanical dispersion : Solid material is first finely ground by usual methods. It is then mixed with dispersion medium which gives a coarse suspension. The suspension is now introduced into the colloid mill. The simplest form of colloid mill consists of two metal discs held at a small distance apart from one another and capable of revolving at a very high speed (about 7000 revolutions per minute) in opposite directions. The particles are ground down to colloidal size and are then dispersed in the liquid . A stabilizer is often added to stabilize the colloidal solution. Colloidal graphite (a lubricant) and printing ink



are made by this method. Tannin is used as a stabilizer in the preparation of colloidal graphite and gum arabic in lampblack colloidal solution (Indian ink).

(B) Electro-dispersion (Bredig's arc method) : This method is suitable for the preparation of colloidal solutions of metals like gold, silver, platinum, etc. An arc is struck between the metal electrodes under the surface of water



container in an ice bath. The intense heat of the arc vaporises some of the metal which condenses under cold water.

(C) Ultrasonic dispersion : The sound waves of high frequency are usually called ultrasonic waves. These waves can be produced when quartz crystal discs are connected with a high frequency generator. The application of ultrasonic waves for the preparation of colloidal solutions was first introduced by wood and Loomis, in 1927. Various substances like oils, mercury, sulphur, sulphides and oxides of metals can be dispersed into colloidal state very easily with the help of ultrasonic waves.

(D) Peptization : Peptization may be defined as the process of converting a precipitate into colloidal sol by shaking it with dispersion medium in the presence of a small amount of electrolyte. The electrolyte used for this purpose is called peptizing agent. This method is applied, generally, to convert a freshly prepared precipitate into a colloidal sol. During peptization, the precipitate adsorbs one of the ions of the electrolyte on its surface. This causes the development of positive or negative charge on precipitates, which ultimately break up into smaller particles of the size of a colloid.

A few examples of sols obtained by peptization are :

(i) Freshly prepared ferric hydroxide on treatment with a small amount of ferric chloride solution at once forms a dark reddish brown solution. Ferric chloride acts as a peptizing agent.

(ii) Freshly precipitated silver chloride can be converted into a colloidal solution by a small amount of hydrochloric acid.

(iii) Cadmium sulphide can be peptized with the help of hydrogen sulphide.

(ii) Condensation Methods :

(A) By exchange of solvents : If a solution of sulphur or phosphorus prepared in alcohol is poured into water, a colloidal solution of sulphur or phosphorus is obtained due to low solubility of sulphur or phosphorus is obtained due to low solubility in water. Thus, there are a number of substances whose colloidal solutions can be prepared by taking a solution of the substance in one solvent and pouring it into another solvent in which the substance is relatively less soluble.

(B) By change of physical state : Colloidal solutions of certain elements such as mercury and sulphur are obtained by passing their vapour through cold water containing a stabilizer (an ammonium salt or a citrate)

(C) Chemical methods : Colloidal solutions can be prepared by chemical reactions leading to formation of molecules by double decomposition, oxidation, reduction or hydrolysis. These molecules then aggregate leading to formation of sols.

$$As_2O_3 + 3H_2S \xrightarrow{\text{Double decomposition}} As_2S_3(sol) + 3H_2O$$

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

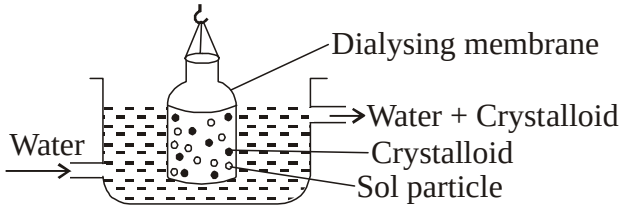
$$2AuCl_3 + 3HCHO + 3H_2O \xrightarrow{\text{Reduction}} 2Au(sol) + 3HCOOH + 6HCl$$

$$FeCl_3 + 3H_2O \xrightarrow{\text{Hydrolysis}} Fe(OH)_3(sol) + 3HCl$$

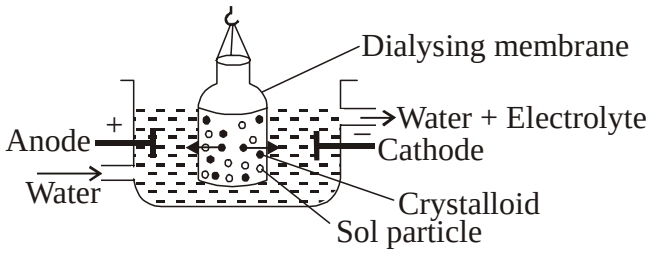
4.5 PURIFICATION OF COLLOIDAL SOLUTIONS :

Colloidal solutions prepared by above methods generally contain excessive amount of electrolytes and some other soluble impurities. The presence of traces of electrolyte is essential for the stability of the colloidal solution but larger quantities coagulate it. It is, therefore, necessary to reduce the concentration of these soluble impurities to a requisite minimum. The process used for reducing of these impurities to a requisite minimum is known as purification of colloidal solution. The purification of colloidal solution is carried out by the following methods.

(i) Dialysis : It is a process of removing a dissolved substance from a colloidal solution by means of diffusion through suitable membrane. Since, particles in true solution (ions or smaller molecules) can pass through animal membranes (bladder) or parchment paper or cellophane sheet but colloidal particles do not, the above can be used for dialysis. The apparatus used for this purpose is called **dialyser**. A bag of suitable membrane containing the colloidal solution is suspended in a vessel through which fresh water is continuously flown figure. The dissolved substances and ions diffuse through the membrane into the outer water and pure colloidal solution is left behind.



(ii) Electro-dialysis : Ordinarily, the process of dialysis is quite slow. It can be made faster by applying an electric field if the dissolved substance in the impure colloidal solution is only electrolyte. The process is then named electro-dialysis. The colloidal solution is placed between two electrodes while pure water is taken in a compartment on each side. Electrodes are fitted in the compartment as shown in figure the ions present in the colloidal solution migrate out to the oppositely charged electrodes.



(iii) Ultrafiltration : Ultrafiltration is the process of separating the colloidal particles from the solvent and soluble solutes present in the colloidal solution by especially prepared filters, which are permeable to all substances except the colloidal particles.

Colloidal particles can pass through ordinary filter paper because the pores are too large. However, the pores of filter paper can be reduced in size by impregnating with collodion solution and subsequently hardened by soaking in formaldehyde. The usual colloidion is a 4% solution of nitro-cellulose in a mixture of alcohol and ether. An ultrafilter paper may be prepared by soaking the filter paper in a colloidion solution and hardened by formaldehyde and finally drying it. Thus, by using ultrafilter paper, the colloidal particles are separated from rest of the materials. Ultrafiltration is a slow process. To speed up the process, pressure or suction is used.

The colloidal particles left on the ultrafilter paper are then stirred with fresh dispersion medium (solvent) to get a pure colloidal solution.

4.6 PROPERTIES OF COLLOIDAL SOLUTIONS :

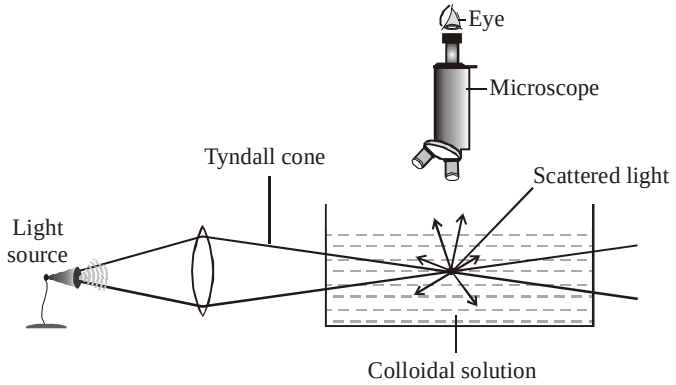
4.6.1 Colligative properties:

Colloidal particles being bigger aggregates, the number of particles in a colloidal solution is comparatively small as compared to a true solution. Hence, the values of colligative properties (osmotic pressure, lowering in vapour pressure, depression in freezing point and elevation in boiling point) are of small order as compared to values shown by true solutions at same concentrations.

4.6.2 Optical Properties :

(I) Tyndal Effect : When a strong and converging beam of light is passed through a colloidal solution, its path becomes visible (bluish light) when viewed at right angles to the beam of light. This effect is called **Tyndall effect**. The light is observed as a bluish cone which is called **Tyndall cone**.

The Tyndall effect is due to scattering of light by the colloidal particles. The scattering of light cannot be due to simple reflection, because the size of the particles is smaller than the wave, length of the visible light and they are unable to reflect light waves. In fact, colloidal particles first absorb light and then a part of the absorbed light is scattered from the surface of the colloidal particles as a light of shorter wavelength. Since maximum scattering of light takes place at right angles to the place of incident light, it becomes visible when seen from that direction.



Tyndall effect

The Tyndall effect is observed under the following conditions :

(i) The diameter of the dispersed particles must not be much smaller than the wavelength of light employed.

(ii) The refractive indices of the dispersed phase and the dispersion medium must differ widely. This condition is fulfilled by lyophobic colloids.

It is important to note that Tyndall effect is not shown by true solutions as their particles are too small to cause scattering.

Note :

Tyndall effect is used to distinguish between a colloidal and true solution. Zsigmondy, in 1903, used Tyndall effect to set up an apparatus known as ultramicroscope. An intense beam of light is focussed on the colloidal solution contained in a glass vessel. The focus of the light is then observed with a microscope at right angles to the beam. Individual colloidal particles appear as bright stars against a dark background. Ultramicroscope does not render the actual colloidal particles visible but only observe the light scattered by them. Thus, ultramicroscope does not provide any information about the size and shape of colloidal particles.

(II) Colour : The colour of the colloidal solution is not always the same as the colour of the substances in the bulk. The colour of the colloidal solution depends upon the following factors :

(a) Size and shape of colloidal particles.

(b) Wavelength of the light scattered by dispersed particles.

(c) The way an observer receives the light, i.e., whether by reflection or by transmission.

Examples :

(i) Finest gold is red in colour. As the size of particles increases, it appears purple, then blue and finally golden.

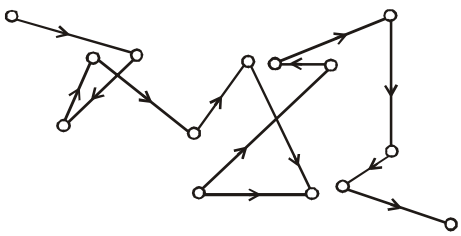
(ii) Dilute milk gives a bluish tinge in reflected light whereas reddish tinge in transmitted light.

4.6.3 Mechanical Properties :

(a) Brownian movement : Colloids particles exhibit a ceaseless random and swarming motion. This kinetic activity of particles suspended in the liquid is called Brownina movement.

Robert Brown a British Botanist first observed this motion with pollen grains suspended in water.

Cause of movement : The Brownian movement has been explained to be due to the unbalanced bombardment of the particles by the molecules of the dispersion medium. The Brownian movement has a stirring effect which does not permit the particles to settle and thus, is responsible for the stability of sols.



Brownian movement

Importance :

Brownian movement does not allow the colloidal particles to settle down due to gravity and thus is responsible for their stability.

4.6.4 Electrical Properties :

(I) Charge of colloidal particles :

Origin of charge : Various reasons have been given regarding the original of charge on the colloidal particles. These are given below :

(i) Frictional electrification : It is believed to be frictional due to the rubbing of the dispersed phase particles with medium molecules.

(ii) Dissociation of the surface molecules : It leads to electric charge on colloidal particles. For example, an aqueous solution of a soap (sodium palmitate) dissociates into ions.

$C_{15}H_{31}COONa \rightleftharpoons C_{15}H_{31}COO^- + Na^+$

sod. palmitate

The Na^+ ions pass into the solution while $C_{15}H_{31}COO^-$ ions have a tendency to form aggregates due to weak attractive forces present in the hydrocarbon chains. Thus, the anions which are of colloidal size bear negative charge.

(iii) Preferential adsorption of ions from solution : The charge on the colloidal particles is generally acquired by preferentially adsorbing positive or negative ions from the electrolyte. Thus AgCl particles can adsorb Cl^- ions from chloride solutions and Ag^+ ions from excess Ag^+ ions solutions; the sol. will be negatively charged in the first case and positively charged in the second case.

(iv) Capture of electron : It is from air during preparation of sol. by Bredig's arc method.

(v) Dissociation of molecular electrolytes on the surface of particles : H_2S molecules get adsorbed on sulphides during precipitation. By dissociation of H_2S, H^+ ions are lost and colloidal particles become negatively charged.

Colloidal particles always carry an electric charge. The nature of this charge is the same on all the particles in a given colloidal solution and may be either positive or negative. A list of some common sols with the nature of charge on their particles is given below:

Positively charged sols	Negatively charged sols
Hydrated metallic oxides, e.g. $Al_2O_3.xH_2O$, $CrO_3.xH_2O$ and $Fe_2O_3.xH_2O$, etc.	Metals, e.g. copper, silver, gold sols.
Basic dye stuffs, e.g., methylene blue sol.	Metallic sulphide, e.g., As_2S_3, Sb_2S_3, CdS sols.
Haemoglobin (blood)	Acid dye stuffs, e.g. eosin congo red sols.
Oxides, e.g. TiO_2 sol.	Sols of starch, gum, gelatin, clay, charcoal, etc.

The charge on the sol particles is due to one or more reasons, viz., due to electron capture by sol particles during electrodispersion of metals, due to preferential adsorption of ions from solution and/or due to formulation of electrical double layer. Preferential adsorption of ions is the most accepted reason. The sol particles acquire positive or negative charge by preferential adsorption of positive or negative ions. When two or more ions are present in the dispersion medium, preferential adsorption of the ion common to the colloidal particle usually takes place. This can be explained by taking the following examples:

(a) When silver nitrate solution is added to potassium iodide solution, the precipitated silver iodide adsorbs iodide ions from the dispersion medium and negatively charged colloidal solution results. However, when KI solution is added to $AgNO_3$ solution, positively charged sol results due to adsorption of Ag+ ions from dispersion medium.

AgI/I^- AgI/Ag^+

Negatively charged Positively Charged

(b) If $FeCl_3$ is added to excess of hot water, a positively charged sol of hydrated ferric oxide is formed due to adsorption of Fe^{3+} ions. However, when ferric chloride is added to NaOH a negatively charged sol is obtained with adsorption of OH^- ions.

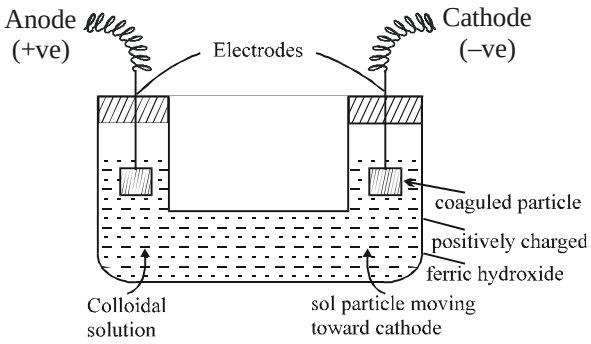
$Fe_2O_3.xH_2O/Fe^{3+}$ $Fe_2O_3.xH_2O/OH^-$

Positively charged Negatively charged

Having acquired a positive or a negative charge by selective adsorption on the surface of a colloidal particle as stated above, this layer attracts counter ions from the medium forming a second layer, as shown below.

$AgI/I^- K^+$ AgI/Ag^+I^-

(II) Electrophoresis : In a colloidal solution, the colloidal particles are electrically charged and the dispersion medium has equal but opposite charge. Thus colloidal solution on the whole is electrically neutral. When an electric current is passed through a colloidal solution, the charged particles move towards the oppositely charged electrode where coagulate due to loss of charge.

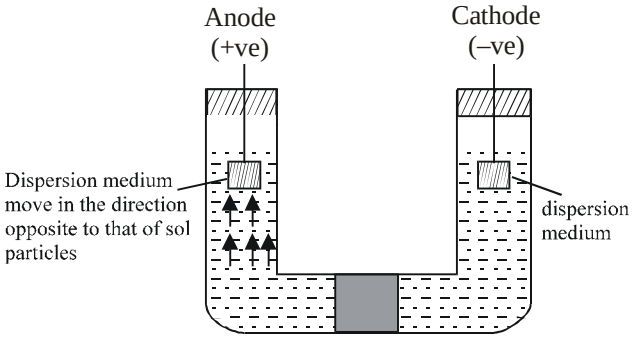


The phenomenon involving the migration of colloidal particles under the influence of electric field towards the oppositively charged electrode, is called electrophoresis or cataphoresis.

This phenomenon is used to determine the charge on the colloidal particles. For example, when a sol. of ferric hydroxide is taken in a U-tube and subjected to electric field, the ferric hydroxide (sol.) particles get accumulated near the cathode. This shows that ferric hydroxide sol. particles are positively charged.

(III) Electro-osmosis : The phenomenon involving the migration of the dispersion medium and not the colloidal particles under the influence of an electric field is electro-osmosis.

Take the pure solvent (dispersion medium) in two limbs of U-tube. In the lower middle portion of U-tube, a porous diaphragm containing the colloidal system is present which divides the U-tube in two sections. In each section of U-tube, an electrode is present, as shown in figure. When the electrode potential is applied to the electrodes, the solid phase of sol. (colloidal system) cannot move but the solvent (dispersion medium) moves through the porous diaphragm towards one of the electrodes. The direction of migration of dispersion medium due to electro-osmosis determines the charge on sol. particles e.g., if the dispersion medium moves towards the cathode (negative electrode), the sol. particles are also negatively charged because the dispersion medium is positively charged as on the whole colloidal solution is neutral.



(IV) Zeta poential, ξ : The combination of the two layers of opposite charges around the colloidal particle is called **Helmholtz electrical double layer**. According to modern views, the first layer of ions is firmly held and is termed **fixed layer** while the second layer is mobile which is termed **diffused layer**. Since separation of charge is a seat of potential, the charges of opposite signs on the fixed and diffused parts of the double layer results in a difference in potential between these layers. This potential difference between the fixed layer and the diffused layer of opposite charges is called the **electrokinetic potential or zeta potential**. The presence of equal and similar charges on colloidal particles is largely responsible in providing stability to the colloidal solution, because the repulsive forces between charged particles having same charge prevent them from coalescing or aggregating when they come closer to one another.

(V) Isoelectric point : It is the pH at which the colloidal particles do not carry any charge.

4.7 COAGULATION :

The colloidal sols are stable due to the presence of electric charges on the colloidal particles. Because of the electrical repulsion, the particles do not come close to one another to form precipitates. The removal of charge by any means will lead to the aggregation of particles and hence precipitation will occur immediately.

This process by means of which the particles of the dispersed phase in a sol. are pecipitated is known as coagulation.

If the coagulated particles instead of settling at the bottom of the container, float on the surface of the dispersion medium, the coagulation is called flocculation.

Most of the sols are coagulated by adding an electrolyte of opposite sign. This is due to the fact that the colloidal particles take up the ions of electrolyte whose charges are opposite to that on colloidal particles with the result that charge on the colloidal particles is neutralized. Thus coagulation takes place. For example, arsenius sulphide sol. (negatively charged) precipitated by adding barium chloride solution. It is due to the fact that the negatively charged particles of the sol. take up barium ions and get neutralized which lower the stability. As a result coagulation takes place.

It is observed that different amounts of different electrolytes is required to bring coagulation of a particular solution.

The minimum concentration of an electrolyte in millimoles per litre required to cause precipitation of one litre of a colloidal solution in two hours is called **(coagulation in value or flocculation value)** of the electrolyte for the sol. The smaller the quantity needed the higher will be the coagulating power of an ion.

The reciprocal of coagulation value is regarded as the coagulating power the

For example, the coagulation values of NaCl, $BaCl_2$ and $AlCl_3$ for arsenic sulphide sol. are 51, 0.69 and 0.093 millimoles/litre respectively. Thus their coagulating powers are $\frac{1}{51}$, $\frac{1}{0.69}$ and $\frac{1}{0.093}$ i.e., 0.0196, 1.449 and 10.75 respectively.

The coagulation values of a few electrolytes for negatively charged arsenic sulphide and positively charged ferric hydroxide sol. are given in table given below. The valency of the coagulation ion (the ion whose charge is opposite to that of the colloidal particles) is also given.

Coagulation values of different electrolytes

Arsenic sulphide sol.			**Ferric hydroxide sol.**		
Electrolyte coagulating cation	Valency of cation	coagulation value	Electrolyte coagulating	Valency of anion	coagulation value
K_2SO_4	1	63	KBr	1	138
NaCl	1	51	KNO_3	1	132
KNO_3	1	50	KCl	1	103
$MgSO_4$	2	0.81	K_2CrO_4	2	0.320
$BaCl_2$	2	0.69	K_2SO_4	2	0.215
$AlCl_3$	3	0.093	$K_3Fe(Cn)_6$	3	0.096

From the above table, it is clear that the coagulating power of Al^{3+} ions in precipitating the arsenic sulphide sol. is approximately 550 times more than that of sodium (Na^+) or potassium (K^+) ions. Again, it is observed that the negatively charged arsenic sulphide sol. is coagulated by cations while positively charged ferric hydroxide sol. is coagulated by anions.

Hardy-Schulz rules : H. Schulze (1882) and W.B. Hardy (1900) suggested the following rules to discuss the effect of electrolytes of the coagulation of the sol.

(1) Only the ions carrying charge opposite to the one present on the sol. particles are effective to cause coagulation, e.g., the negative charged sol. is best coagulated by cations and a positive sol. is coagulated by anions.

(2) The charge on coagulating ion influences the coagulation of sol.
In general, the coagulating power of the active ion increases with the valency of the active ion. After observing the regularities concerning the valency of the active ion, a law was proposed by Hardy and Schulz which is termed as Hardy-Schulze law which is stated as follows:
"Higher is the valency of the active ion, greater will be its power to precipitate the sol."

Thus, coagulating power of cations is in the order of $Al^{3+} > Ba^{2+}$ or $Mg^{2+} > Na^+$ or K^+.

Similarly, to coagulating the positively charged sol. the coagulating power of anion is in the order of $[Fe(CN)_6]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^-$

Ex3. 11.7 gm NaCl is needed for complete coagulation on 50 l of a colloidal solution. What is the coagulation value of electrolyte ?

Sol. $\textit{Coagulation value} = \dfrac{\text{millimole of electrolyte}}{\text{L of colloidal solution}} = \dfrac{\frac{11.7}{58.5}\times 1000}{50} = 4$

Some other methods of coagulation :

Apart from the addition of electrolyte, coagulation can also be carried out by following methods:

(i) **By persistent dialysis :** It has been observed that traces of electrolytes are associated with the solution due to which it is stable. If the solution is subjected to prolonged dialysis, the traces of electrolytes are removed and coagulation takes place.

(ii) **By mutual coagulation of colloids :** When two sols of oppositively charges are mixed together in a suitable proportion, the coagulation takes place. The charge of one is neutralized by the other. For example, when negatively charged arsenic sulphide sol. is added to positively charged ferric hydroxide sol., the precipitation of both occurs simultaneously.

(iii) **By electrical method :** If the electrical charge of lyophobic sol. is removed by applying any electric field such as in electrophoresis, they also precipitate out.

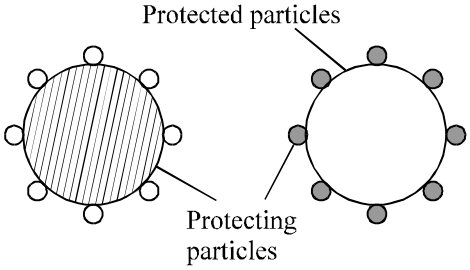
(iv) **By boiling:** When a sol is boiled, the adsorbed layer is disturbed due to increased collisions with the molecules of dispersion medium. This reduces the charge on the particles and ultimately lead to settling down in the form of a precipitate.

(v) **By addition of electrolytes:** When excess of an electrolyte is added, the colloidal particles are precipitated. The reason is that colloids interact with ions carrying charge opposite to that present on themselves. This causes neutralisation leading to their coagulation. The ion responsible for neutralisation of charge on the particles is called the coagulating ion. A negative ion causes the precipitation of positively charged sol and vice versa.

4.8 PROTECTIVE COLLOIDS :

Lyophilic sols are more stable than the lyophobic sols. This is because, lyophilic colloids are extensively hydrated and these hydrated particles do not combine to form large aggregates.

Lyophobic sols are more easily coagulated by the addition of suitable electrolyte. To avoid the precipitation of lyohobic sol, by the addition of electrolyte, some lyophilic colloid is added to it. Such lyophilic colloid is called protective colloid and the protection of lyophobic colloid from the electrolytes is known as **protection** . The substances commonly used as protective colloids are gelating, albumin, gum arabic, casein, starch, glue etc. A gold sol. containing a little gelatin as protective colloid needs a very large amount of sodium chloride to coagulate the sol.



Explanation : The particles of the protective colloid get adsorbed on the particles of the lyophobic colloid, thereby forming a protective layer around it (figure). The protective layer prevents the precipitating ions from coming in contact with the colloidal particles.

According to a recent view, the increase in stability of the lyophobic colloid is due to the mutual adsorption of the lyophilic and lyophobic colloids. It is immaterial which is adsorbed on which.

Gold number of a protective colloid is a minimum weight of it in milligrams which must be added to 10 ml of a standard red gold sol so that no coagulation of the gold sol. (i.e. change of colour from red to blue) takes place when 1 ml of 10 % sodium chloride solution is rapidly added to it. Obviously, smaller the gold number of a protective colloid, the greater is the protective action.

Ex.4 ***0.02 gm of lyophilic colloid just present coagulation in 10 ml of a lyophobic colloid on adding 1 ml of 10 % NaCl solution. What is the gold number of lyophilic colloid ?***

Sol. ***Mg of lyophilic colloid = 0.02 × 1000 = 20***

4.9 EMULSIONS :

An emulsion is a colloidal solution of a liquid. It may be defined as a heterogeneous system consisting of more than one immiscible liquids dispersed in one another in the form of droplets

For example, milk is an emulsion in which small drops of liquid fat are dispersed in aqueous medium. Cod liver oil is an emulsion in which the water drops are dispersed in the oil. This means in most of the emulsions one of the liquid is water and the other liquid in oil.

The emulsion are classified as :

(1) Oil in water type emulsion (O/W): In this emulsion, oil is the dispersed phase and water is the dispersion medium. It is denoted by O/W or O in W. For example, milk (liquid fat dispersed in water), vanishing cream.

(2) Water in oil type : In this emulsion, water is the dispersed phase and oil is the dispersion medium. It is denoted by W/O or W in O. For example, butter.

The type of emulsion obtained by agitating two immiscible liquids depends upon the relative amounts of two components liquids. The liquid that is in excess forms the dispersion medium. Thus, the two types of emulsions can be interconverted into each other by changing the concentration of one of the liquids.

4.9.1 Preparation of emulsion (Emulsification) : Emulsification is the process which involves the preparation of emulsion. Generally, an emulsion is prepared by subjecting a mixture of the immiscible liquid to a distinct layers upon standing. The oil globules rise to form an upper layer while aqueous medium forms lower layers. To prevent the separation of layers and to get the stable emulsion, a small quantity of the third substance is added. This substance which stabilizes the emulsion is called emulsifier or emulsifying agent. The commonly used emulsifying agents are soaps, detergents and lyophilic colloids. Casein, a lyophilic colloid present in milk, acts as an emulsifier as it forms a protective layer around fat molecules dispersed in water. Hence milk is a fairly stable emulsion.

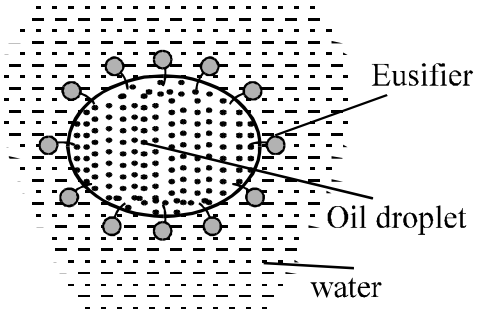
Function of emulsifier : The main function of emulsifier or emulsifying agents is to lower the interfacial tension between oil and water and thus helps the intermixing of two liquids. For example, a molecule of a soap or detergent (emulsifier) gets concentrated at the interface between oil and water. The polar end of the emulsifier is in water and non-polar end is in oil as shown in figure.

In a soap, RCOONa, R is the non-polar end, whereas COO^{-} Na^{+} is the polar end.

4.9.2 Properties of emulsion :

(i) The size of particles of the dispersed phase of an emulsion is usually larger than in sols.

(ii) Like colloidal particles, emulsions exhibit properties such as Tyndall effect, Brownian movement (provided the particles are not too large), electrophoresis, coagulation, etc.



Demulsification : The process which involves the breaking of an emulsion into two separate liquid layers is called demulsification. The following methods may be used to bring demulsification:

(1) **Chemical Methods :** An emulsion may be demulsified by adding a chemical substance whose action on the dispersed phase and the dispersion medium is opposite to that of the original emulsifying agent used to produce the stable emulsion.

(2) **Centrifugation :** Cream is separated from milk by the centrifugal method.

(3) **Cooling :** Fat can be removed from milk by keeping it in a refrigerator for a few hours.

4.9.3 Oil in water type emulsion (O/W) Use of emulsion :

(1) Many pharmaceutical preparations-medicines, ointments, creams and various lotions are emulsions. It is believed that medicines are more effective and easily assimilated by the body tissues when they are in colloidal form i.e., emulsion.

(2) All paints are emulsions.

(3) The digestion of fat in the intestines is helped by emulsification. A little of the fat forms a medium soap (emulsifier) with the alkaline solution of the intestine and this soap emulsifier the rest of the fats, thus making it easier for the digestive enzymes to do their metabolic functions.

(4) Soaps and detergents remove dust and dirt from the dirty piece of cloth by making an oil in water emulsion.

(5) Milk is an emulsion of liquid fats in water.

(6) In the process of metallurgy, one of the important steps is the concentration of ore which is usually done by froth floatation process in which an oil is added to the finely-divided ore taken in water. The particles of ore go on the surface due to formation of foams while the other impurities are left at the bottom of the vessel.

(7) The emulsion of asphalt in water is used in road making and building.

4.10 USES OF COLLOIDS :

(1) **Medicines :** The medicines containing gold, silver or calcium etc. in colloidal form are more effective and easily assimilated by the human systems.

(2) **Dyes :** In dyeing, mordants colloidal substances are used in textile dyeing industry to fasten dyes.

(3) **Rubber industry :** Latex is a colloidal solution of negatively charged particles. The article to be rubber plated is made the anode. Under the influence of electric field the rubber particles get deposited on the anode and the article gets rubber plated.

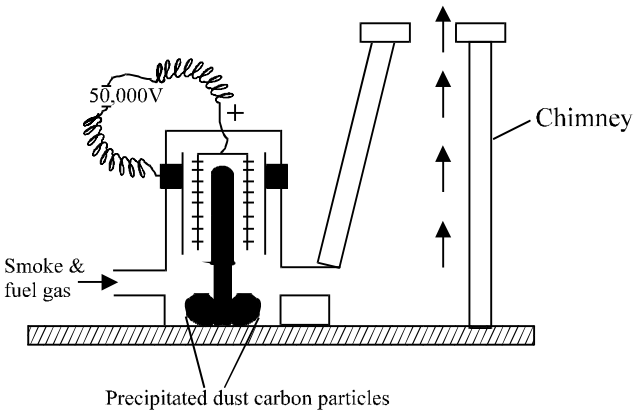
(4) **Smoke screens :** Smoke screens which consist of titanium dioxide dispersed in air are used in warfare for the purpose of concealment and camouflage.

(5) **Formation of delta :** The river waver carries with it charged clay particles and many other substances in the form of colloidal solution. When the sea water comes in contact with these particles, the colloidal particles in river water are coagulated by the electrolytes present in sea water to form deltas.

(6) **Purification of water :** The turbidity in water is due to the presence of negatively charged clay particles. The addition of potash alum, i.e., Al^{3+} ions neutralizes the negative charge on the colloidal particles and thus causes their coagulation. The coagulated matter settles down and thus becomes clear.

(7) **Artificial rain :** Artificial rain can be caused by throwing electrified sand on clouds which are colloidal solutions or charged particles of water in air.

(8) **Smoke precipitation :** Smoke coming out of the chimney is industrial area is a nuisance and health hazard. It is a colloidal particles are charged particles and thus they are removed from fuel gases by electrical precipitation (Cottrell Precipitator).



In cottrell precipitator, the smoke is made to pass through chambers fitted with highly electrically charged plates which precipitate the carbon and dust particles leaving in the gases to escape through chimney (figure).

(9) **Sewage disposal :** Sewage water consists of particles of dirt, rubbish, mud, etc., which are of colloidal dimensions and carry an electric charge and thus do not settle down easily. These particles can thus be removed by cataphoresis. A system of two tanks fitted with metallic electrodes is used for this purpose. When electric field is created, then the dust particles are coagulated on he oppositely charged electrodes. The deposit may be utilized as a manure.

(10) **Cleansing action of soap and detergent :** Soap solution may be used to wash off the dirt sticking to the fabric, in the presence

(i) If forms a collodial solution in water forms (miscelles), removes dirt by simple adsorption of oily substance and thus washes away.

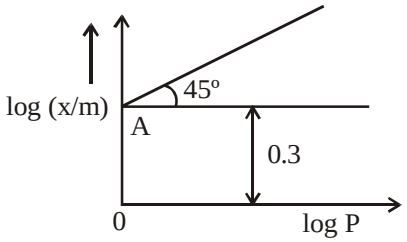
(ii) It decreases the interfacial tension between water and grease, and it causes the emulsification of grease in water. By mechanical action such as rubbing, the dirt particles are also detached alongwith the only material.

(11) **In Photography :** Various colloidal system are used in photographic process. In the preparation of photographic plates, the silver bromide in gelatin is coated on thin glass plates. In developing and fixation, various colloidal substances are used. In different kinds of colour printing, gelatin and other colloidal mixtures are used.

(12) **Blue colour of the sky :** Colloidal particles scatter only blue light and the rest of is absorbed. In sky there are a number of dust and water particles. They scatter blue light and, therefore, sky looks bluish. If there were no scattering, the sky would have appeared totally dark.

EXERCISE # S-1

1. Graph between $\log\left(\frac{x}{m}\right)$ vs log P is provided for adsorption of NH_3 gas on metal surface. Calculate weight of NH_3 gas adsorbed by 50 gm of metal surface at 2 atm pressure



SC0001

2. When a graph is plotted between *log x/m* and *log P* (where P is in atm), it is straight line with an angle of 45° and intercept 0.3010 on y-axis, what will be the amount of gas adsorbed per gm of adsorbent at pressure 0.3 atm (log2 = 0.3010)

SC0002

3. In vessel O_2 gas undergoes physisorption on adsorbent surface causing its partial pressure to decrease from 6 atm to 'P' atm in a 8.21 L vessel at 500K. If total number of sites is 2×10^{23} on adsorbent surface and every site accommodates effectively three O_2 molecules find P(atm).

[$N_A = 6 \times 10^{23}$]

SC0003

4. 1.25 mg of Gum Arabica (Gold Number = 0.25) is added to 50 ml of standard gold sol. What maximum volume (in ml) of 10% NaCl solution can be added to this gold sol without causing coagulation.

SC0004

5. Gold number of haemoglobin is 0.3. Calculate weight (in mg) of haemoglobin for 100 ml of gold sol so that gold sol is not coagulated by 10 ml of 10% NaCl solution.

SC0005

6. A soap ($C_{17}H_{35}$ COONa) solution becomes a colloidal sol at a concentration of 1.2×10^{-3} M. On the average, 2.4×10^{13} colloidal particles are present in 1 mm^3. What is the average number of stearate ions in one colloidal particle (micelle) : **Take : Avogadro's number = 6×10^{23}**

SC0006

7. How many of the following phenomenon are observed due to process of coagulation.

(A) Delta formation at the meeting point of river and sea.

(B) Blue colour of sky.

(C) Precipitation of coal ash from smoke in chimeney's.

(D) destruction of lyophobic solution.

(E) Brownian motion.

(F) Cleaning action of detergents.

(G) Artificial rain.

(H) Use of alums in cleaning water.

SC0007

8. Calculate the number of sols which are negatively charged.

$Fe_2O_3.xH_2O$ sol	Sb_2S_3 sol
Ag sol	Cu sol
Blood	basic dye
sol of clay	sol of starch
sol of sodium stearate	sol of sodium laurylsulphate
sol of charcoal.	

SC0008

9. In order to cause coagulation of 200 ml of gold sol, 585 ml of 1% w/w NaCl solution having density 1.2 gm/ml was required. What will be the coagulation value of NaCl?

[express answer in milli-moles /litre]

SC0009

10. Molecular formula of starch can be represented as $(C_6H_{10}O_5)_n$. If the gold number of one such starch molecule is 6.48 and 0.01 millimoles of the above starch are required to be added to 10ml of gold sol to prevent coagulation by 1 ml of 10% sodium chloride solution, then calculate the value of 'n'.

SC0010

EXERCISE # S-2

1. In a vessel O_2 gas molecules were adsorbed on solid surface causing its partial pressure to decreases from 1 atm to 0.5 atm.

Given : $N_A = 6 \times 10^{23}$

Volume of vessel = 2.24 L

Temperature = 273 K

Total area of solid surface = 10^2 cm^2

Number of active sites per unit area = 10^{24} m^{-2}

Find number of O_2 molecules adsorbed per active site.

SC0011

2. A 0.03 M of an acid solution in benzene is dropped on water surface, the benzene evaporates and the acid forms a monomolecular film of solid type. What volume (in ml) of the above solution would be required to cover a 54000cm^2 surface area of water with monomolecular layer of acid. Area covered by single acid molecule is 0.3nm^2 ($N_A = 6 \times 10^{23}$)

SC0012

3. The diameter of a colloidal particle is 5000 Å. If the density of substance formed , dispersed phase, is 4gm/cc, find the value of surface area per unit mass of colloidal particle in (m^2/gm).

SC0013

4. A container contains 1 litre, 2M solution of benzene in ether. A piece of 3 kg charcoal is dipped in the solution. Molecules of benzene get adsorbed on the surface of charcoal and form monolayer. The molarity of resulting solution decreases to 1M. If surface area available for adsorption on charcoal $12\sqrt{3}$ cm^2/gm. Then find distance (in Å) between two adjecent carbon atoms in a benzene molecule.

(Assume: Shape of benzene molecule perfectly hexagonal.)

[Use: $N_A = 6 \times 10^{23}$]

SC0014

5. 112cm^3 hydrogen gas is adsorbed uniformly at the surface of 5 gm Palladium at 273°C and 2 atm. If the effective surface area of each hydrogen molecule is 0.4 nm^2, then the specific surface area of Palladium is :

SC0015

6. The desorption of gas molecules from the adsorbent surface obeys Arrhenius equation. The average time upto which a N_2 molecule may remain adsorbed at Pt-surface at 400K is

[Given: Pre-exponential factor, $A = 1.25 \times 10^8\ s^{-1}$;

Activation energy of desorption = 16Kcal, $e^{20} = 5 \times 10^8$]

SC0016

7. A colloid prepared by the addition of KI to $AgNO_3$ solution is purified using dialysis. Find the minimum mass in grams of an electrolyte 'AB' (GMM = 60) required to completely coagulate 1ℓ of the aforementioned colloid

Given :

Active ion causing flocculation	Flocculation value(mmole/*l*)
A^+	50
B^-	100

SC0017

8. At 70K, the adsorption of N_2 gas at iron surface obeys Freundlich adsorption isotherm. The experimental data collected is

P(bar)	4	25	64
$\frac{x}{m}$	0.2	0.5	0.8

Where $\frac{x}{m}$ is the mass (in gm) of N_2 gas adsorbed per gm of iron at P bar pressure. The moles of N_2 gas adsorbed per gm of iron at 36 bar and 70 K, is

SC0018

9. 1.9×10^{-4} gm of the metal having density 19 gm/ml is dispersed in one litre of water to give a sol having spherical metal particles of radius 10 nm. The approximate number of metal sol particles per cm^3 of the sol is given by :

SC0019

10. If unit mass of a solid, taken as cube of volume 8 cm^3, is powdered into identical 10^{12} cubes, then the specific surface area of the solid increased by :

SC0020

EXERCISE # O-I

Select the correct alternative. (Only one is correct)

1. Which gas will be adsorbed on a solid to greater extent.
(A) A gas having non polar molecule
(B) A gas having highest critical temperature (T_c)
(C) A gas having lowest critical temperature.
(D) A gas having highest critical pressure.

SC0021

2. The heat of physisorption lie in the range of
(A) 1 – 10 kJ mol^{-1} (B) 20 to 40 kJ mol^{-1}
(C) 40 to 200 kJ mol^{-1} (D) 200 to 400 kJ mol^{-1}

SC0022

3. Adsorption is multilayer in case of
(A) physical adsorption (B) chemisorption
(C) in both (D) none of the these

SC0023

4. Reversible adsorption is
(A) chemical adsorption (B) physical adsorption
(C) both (D) none

SC0024

5. An emulsion is a colloidal system of
(A) two solids (B) two liquids
(C) one gas and one solid (D) one gas and one liquid

SC0025

6. The nature of bonding forces in chemisorption
(A) purely physical such as Van Der Waal's forces
(B) purely chemical
(C) both chemical and physical simultaneously.
(D) none of these

SC0026

7. The Tyndall effect associated with colloidal particles is due to
(A) presence of electrical charges (B) scattering of light
(C) absorption of light (D) reflection of light

SC0027

8. Which one of the following is not applicable to chemisorption?
(A) Its heat of adsorption is high (B) It takes place at high temperature
(C) It is reversible (D) It forms mono-molecular layers

SC0028

9. In the colloidal state the particle size ranges
(A) below 1 nm (B) between 1 nm to 1000 nm
(C) more than 1000 nm (D) none of the above

SC0029

10. Colloids can be purified by
(A) condensation (B) peptization (C) coagulation (D) dialysis
SC0030

11. Milk is an example of
(A) emulsion (B) suspension (C) foam (D) sol.
SC0031

12. Colloidal particles in a sol. can be coagulated by
(A) heating (B) adding an electrolyte
(C) adding oppositely charged sol (D) any of the above methods
SC0032

13. Emulsifier is an agent which
(A) accelerates the dispersion (B) homogenizes an emulsion
(C) stabilizes an emulsion (D) aids the flocculation of an emulsion
SC0033

14. Fog is a colloidal system of
(A) gas in liquid (B) liquid in gas (C) gas in gas (D) gas in solid
SC0034

15. Given below are a few electrolytes, indicate which one among them will bring about the coagulation of a gold sol. quickest and in the least of molar concentration?
(A) NaCl (B) $MgSO_4$ (C) $Al_2(SO_4)_3$ (D) $K_4[Fe(CN)_6]$
SC0035

16. When a lyophobic colloidal solution is observed , we can see
(A) light scattered by colloidal particle
(B) size of the colloidal particle
(C) shape of the colloidal particle
(D) relative size of the colloidal particle
SC0036

17. The electrical charge on a colloidal particle is indicated by
(A) Brownian movement (B) electrophoresis
(C) ultra microscope (D) molecular sieves
SC0037

18. The minimum concentration of an electrolyte required to cause coagulation of a sol is called
(A) flocculation value (B) gold number (C) protective value (D) none of these
SC0038

19. Smoke precipitator works on the principle of
(A) distribution law (B) neutralization of charge on colloids
(C) Le-Chaterlier's principle (D) addition of electrolytes
SC0039

20. Which one of following statements is not correct in respect of lyophilic sols?
(A) There is a considerable interaction between the dispersed phase and dispersion medium
(B) These are quite stable and are not easily coagulated
(C) They need stabilizing agent
(D) The particle are hydrated

SC0040

21. As_2S_3 sol is
(A) positive colloid (B) negative colloid (C) neutral colloid (D) none of the above

SC0041

22. At the critical micelle concentration (CMC) the surfactant molecules
(A) decompose (B) dissociate
(C) associate (D) become completely soluble

SC0042

23. Small liquid droplets dispersed in another liquid is called
(A) suspension (B) emulsion (C) gel (D) true solution

SC0043

24. The process which is catalysed by one of the product is called
(A) acid-base catalysis (B) autocatalysis
(C) negative catalysis (D) homogeneous catalysis

SC0044

25. Tyndal effect would be observed in a
(A) solution (B) solvent (C) precipitate (D) colloidal sol.

SC0045

26. A liquid is found to scatter a beam of light but leaves no residue when passed through the filter paper. The liquid can be described as
(A) a suspension (B) oil (C) a colloidal sol. (D) a true solution

SC0046

27. The ability of an ion to bring about coagulation of a given colloid depends upon
(A) its charge (B) the sign of the charge alone
(C) the magnitude of the charge (D) both magnitude and sign of charge

SC0047

28. An arsenious sulphide sol. carries a negative charge. The maximum precipitating power of this sol. is possessed by
(A) K_2SO_4 (B) $CaCl_2$ (C) Na_3PO_4 (D) $AlCl_3$

SC0048

29. Which of the following is an example of associated colloid?
(A) Protein + water (B) Soap + water (C) Rubber + benzene(D) $As_2O_3 + Fe(OH)_3$

SC0049

30. Although nitrogen does not adsorb on surface at room temperature, it adsorbs on surface at 83K. Which one of the following statements is correct -
(A) At 83K, there is formation of monomolecular layer
(B) At 83K, there is formation of multimolecular layer
(C) At 83K, nitrogen molecules are held by chemical bonds
(D) At 83K, nitrogen is adsobed as atoms.

SC0050

31. Gold number of a lyophilic sol is such a property that :
(A) The larger its value, the greater is the peptizing power
(B) The lower its value, the greater is the peptizing power
(C) The lower its value, the greater is the protecting power
(D) The larger its value, the greater is the protecting power

SC0051

32. Which of the following statements is incorrect regarding physisorptions ?
(A) Under high pressure it results into multi molecular layer on adsorbent surface
(B) Enthalpy of adsorption ($\Delta H_{adsorption}$) is low and positive
(C) It occurs because of Van der Waal's forces
(D) More easily liquefiable gases are adsorbed readily

SC0052

33. The volume of a colloidal particle V_C, volume of a solute particle in a true solution V_t, the volume of suspension particle is V_S can be arranged
(A) $V_C = V_t = V_S$ (B) $V_S < V_C < V_t$
(C) $V_S > V_C > V_t$ (D) $V_C > V_S > V_t$

SC0053

34. Which of the following is not the property of physi-sorption -
(A) Highly specific in nature (B) Reversible
(C) Multilayer (D) Exothermic

SC0054

35. Arrange the following electrolytes in the increasing order of coagulation power for the coagulation of As_2S_3 sol -
(I) Na_3PO_4 (II) $MgCl_2$ (III) $AlCl_3$
(A) I > II > III (B) I < II < III (C) I = III < II (D) III < I < II

SC0055

36. The gas, which is most readily adsobred on the surface of activated charcoal is -
(A) N_2 (B) H_2 (C) O_2 (D) SO_2

SC0056

37. The migration of colloidal particles under the influence of an electrical field is known as

(A) electro osmosis (B) electrophoresis

(C) electrodialysis (D) None

SC0057

38. Which reaction show the use of heterogenous catalyst

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

(B) $2SO_2(g) + O_2(g) \xrightarrow{Pt(s)} 2SO_3(g)$

(C) $CH_3COOCH_3(l) + H_2O(l) \xrightarrow{HCl(l)} CH_3COOH(aq.) + CH_3OH(aq.)$

(D) All of the above

SC0058

39. Promoters and Poison are the substance use in chemical reaction which

(A) Enhance and decrease the activity of catalyst respectively

(B) Decrease and enhance the activity of catalyst respectively

(C) Do not have any effect on catalyst

(D) Can be used in place of catalyst whenever required

SC0059

40. Peptization process may be defined as

(A) Formation of precipitate by adding two ionic solution

(B) Conversion of colloidal sol into precipitate

(C) Conversion of precipitate into colloidal sol

(D) Enrichment precipitate from solution

SC0060

EXERCISE # O-II

(More than one may be correct)

1. Which of the following is/are correct statements

(A) Hardy Schulz rule is related to coagulation

(B) Brownian movement and Tyndall effect are shown by colloids

(C) When liquid is dispersed in liquid, it is called gel.

(D) Gold number is a measure of protective power of lyophillic colloid.

SC0061

2. Which statements is/are correct?

(A) Physical adsorption is multilayer non-directional and non specific

(B) Chemical adsorption is generally monolayer and specific in nature

(C) Physical adsorption is due to free valence of atoms

(D) Chemical adsorption is stronger than physical adsorption

SC0062

3. Which statement/s is/are correct

(A) A solution is prepared by addition of excess of $AgNO_3$ solution in KI solution. The charge likely to develop on colloidal particle is positive.

(B) The effects of pressure on physical adsorption is high if temperature is low.

(C) Gold number is the index for extent of gold plating done.

(D) None

SC0063

4. Colloidal solution can be purified by

(A) Dialysis (B) Electrodialysis (C) Electrophoresis (D) Ultrafiltration

SC0064

5. Which of the following is not lyophillic

(A) Gelatin sol (B) Silver sol (C) Sulphur sol (D) As_2S_3 sol

SC0065

6. Colloidal Gold can be prepared by

(A) Bredig's are method (B) Reduction of $AuCl_3$

(C) Hydrolysis (D) Peptization

SC0066

7. On adding $AgNO_3$ solution into KI solution , colloidal sol can be obtained from.

(A) 100 mL of 0.1 M $AgNO_3$ + 100 of 0.1 M KI

(B) 100 mL of 0.1 M $AgNO_3$ + 100 of 0.2 M KI

(C) 100 mL of 0.2 M $AgNO_3$ + 100 of 0.1 M KI

(D) 100 mL of 0.15 M $AgNO_3$ + 100 of 0.25 M KI

SC0067

Question No. 8 to 10 (3 questions)

Whenever a mixture of gases is allowed to come in contact with a particular adsorbent under the same conditions, the more strong adsorbate is adsorbed to greater extent irrespective of its amount present, e.g. H_2O is adsorbed to more extent on silica gel than N_2 and O_2. This shows that some adsorbates are preferentially adsorbed. It is also observed that preferentially adsorbable adsorbate can displace a weakly adsorbed substance from the surface of an adsorbent.

8. Which of the following gases is adsorbed to maximum extent:

(A) He (B) Ne (C) Ar (D) Xe

SC0068

9. Which of the gas can displace remaining all the gases

(A) O_2 (B) N_2 (C) CO (D) H_2

SC0069

10. When temperature is increased

(A) extent of adsorption increases (B) extent of adsorption decreases

(C) no effect on adsorption (D) extent of adsorption first decreases, then increases

SC0070

Question No. 11 to 12(2 questions)

In macromolecular type of colloids, the dispersed particles are themselves large molecules (usually polymers). Since these molecules have dimensions comparable to those of colloidal particles, their dispersions are called macromolecular colloids. Most lyophilic sols belong to this category. There are certain colloids which behave as normal strong electrolytes at low concentrations, but exhibit colloidal properties at higher concentrations due to the formation of aggregated particles. These are known as micelles or associated colloids. Surface active agents like soaps and synthetic detergents belong to this class.

CMC increases with the total surfactant concentration. At concentration higher than CMC, they form extended parallel sheets known as **lamellar micelles** which resemble biological membranes. With two molecules thick, the individual molecule is perpendicular to the sheets such that hydrophilic groups are on the outside in aqueous solution and on the inside is a non-polar medium.

In concentrated solutions, micelles take the form of long cylinders packed in hexagonal arrays and are called lytotropic mesomorphs.

In an aqueous solution (polar medium), the polar group points towards the periphery and the hydrophobic hydrocarbon chains point towards the centre forming the core of the micelle.

-They are capable of forming ions

-Molecules of soaps and detergents consist of lyophilic as well as lyophilic parts which associate together to form micelles.

-Micelles may contain as many as 100 molecules or more.

11. Select incorrect statement(s):

(A) Surface active agent like soaps and synthetic detergents are micelles

(B) Soaps are emulsifying agents

(C) $C_{17}H_{35}$ (hydrocarbon part) and $-COO^-$ (carboxylate) part of stearate ion ($C_{17}H_{35}COO^-$) both are hydrophobic

(D) All are incorrect statements

SC0071

12. Cleansing action of soap occurs because:

(A) oil and grease can be absorbed into the hydrophobic centres of soap micelles and washed away

(B) oil and grease can be absorbed into hydrophilic centres of soap micelles and washed away

(C) oil and grease can be absorbed into both hydrophilic and hydrophobic centres but not washed away

(D) cleansing action is not related to micelles

SC0072

Question No.13 to 15 (3 questions)

The protective power of the lyophilic colloids is expressed in terms of gold number a term introduced by Zsigmondy.Gold number is the number of milligram of the protective colloid which prevent the coagulation of 10 ml of red gold sol. when 1 ml of a 10 percent solution of sodium chloride is added to it. Thus, smaller the gold number of lyophilic colloid, the greater is the protective power.

13. On addition of one mL solution of 10% NaCl to 10 mL of red gold sol in presence of 0.025 g of starch, the coagulation is just prevented. The gold number of starch is

(A) 0.025 (B) 0.25 (C) 2.5 (D) 25

SC0073

14. Which of the following statement(s) is/are correct

(A) Higher the gold number, more protective power of colloid

(B) Lower the gold number, more the protective power

(C) Higher the coagulation value, more the coagulation power

(D) Lower the coagulation value, higher the coagulation power

SC0074

15. Gold number gives an indication of

(A) protective nature of colloids

(B) purity of gold in suspension

(C) the charge on a colloidal solution of gold

(D) g-mole of gold per litre

SC0075

Question No. 16 & 19 (4 questions)

These questions consist of two statements each, printed as assertion and reason, while answering these questions you are required to choose any one of the following responses.

(A) If both assertion and reason are true and the reason is a correct explanation of assertion.

(B) If both assertion and reason are true but reason is not a correct explanation of assertion.

(C) If assertion is true but the reason is false.

(D) If assertion is false but the reason is true.

16. **Assertion :** When $AgNO_3$ is treated with excess of potassium iodide, colloidal particles gets attracted towards anode.

Reason : Precipitate adsorb common ions (excess) and thus become charged.

SC0076

17. **Assertion :** For adsorption ΔG, ΔH, ΔS all have –ve values
Reason : Adsorption is a spontaneous exothermic process in which randomness decreases due to force of attraction between adsorbent and adsorbate.

SC0077

18. **Assertion :** A gas with higher critical temperature gets adsorbed to more extent than a gas with lower critical temperature.
Reason : The easily liquifiable gases get adsorbed to less extent.

SC0078

19. **Assertion :** Micelles are formed by surfactant molecules above the critical micellar concentration (CMC).
Reason : The conductivity of a solution having surfactant molecules decreases sharply at the CMC.

SC0079

LIST TYPE :

20.

List-I		**List-II**	
(P)	Inversion of can sugar	(1)	Diastase
(Q)	Conversion of starch into maltose	(2)	Lactor bacilli enzyme
(R)	Conversion of glucose into ethyle	(3)	Invertase
(S)	Conversion of milk into curd	(4)	Zymase

Code :

	P	**Q**	**R**	**S**
(A)	3	4	1	2
(B)	3	4	2	1
(C)	3	1	4	2
(D)	2	4	1	2

SC0080

EXERCISE # J-MAIN

1. Which of the following statements is incorrect regarding physisorptions ? **[AIEEE-2009]**

(1) Under high pressure it results into multi molecular layer on adsorbent surface

(2) Enthalpy of adsorption ($\Delta H_{adsorption}$) is low and positive

(3) It occurs because of Van der Waal's forces

(4) More easily liquefiable gases are adsorbed readily

SC0081

2. According to Freundlich adsorption isotherm, which of the following is correct ? **[AIEEE-2012]**

(1) $\frac{x}{m} \propto p^0$

(2) $\frac{x}{m} \propto p^1$

(3) $\frac{x}{m} \propto p^{1/n}$

(4) All the above are correct for different ranges of pressure

SC0082

3. The coagulating power of electrolytes having ions Na^+, Al^{3+} and Ba^{2+} for aresenic sulphide sol increases in the order :- **[J-Main 2013]**

(1) $Al^{3+} < Ba^{2+} < Na^+$ (2) $Na^+ < Ba^{2+} < Al^{3+}$

(3) $Ba^{2+} < Na^+ < Al^{3+}$ (4) $Al^{3+} < Na^+ < Ba^{2+}$

SC0083

4. A particular adsorption process has the following characteristics: (i) It arises due to van der Waals forces and (ii) it is reversible. Identify the correct statement that describes the above adsorption process:

(1) Enthalpy of adsorption is greater than 100 kJ mol^{-1} **[J-Main 2015]**

(2) Energy of activation is low.

(3) Adsorption is monolayer

(4) Adsorption increases with increase in temperature.

SC0084

5. For a linear plot of log(x/m) versus log p in a Freundlich adsorption isotherm, which of the following statements is correct ? (k and n are constants) **[J-Main 2016]**

(1) log (1/n) appears as the intercept

(2) Both k and 1/n appear in the slope term

(3) 1/n appears as the intercept

(4) Only 1/n appears as the slope

SC0085

6. The Tyndall effect is observed only when following conditions are satisfied **[J- Main (offline)2017]**

(a) The diameter of the dispersed particles is much smaller than the wavelength of the ligh used.

(b) The diameter of the dispersed particle is not much smaller than the wavelength of the light used.

(c) The refractive indices of the dispersed phase and dispersion medium are almost similar in magnitude.

(d) The refractive indices of the dispersed phase and dispersion medium differ greatly in magnitude.

(1) (a) and (d) (2) (b) and (d) (3) (a) and (c) (4) (b) and (c)

SC0086

7. Among the following, correct statement is : **[J- Main (online)2017]**

(1) One would expect charcoal to adsorb chlorine more than hydrogen sulphide.

(2) Brownian movement is more pronounced for smaller particles than for bigger-particles.

(3) Hardy Schulze law states that bigger the size of the ions, the greater is its coagulating power

(4) Sols of metal sulphides are lyophilic

SC0087

8. Adsorption of a gas on a surface follows Freundlich adsorption isotherm. Plot of $\log\frac{x}{m}$ versus log p gives a straight line with slope equal to 0.5, then: **[J- Main (online)2017]**

($\frac{x}{m}$ is the mass of the gas adsorbed per gram of adsorbent)

(1) Adsorption is proportional to the square of pressure.

(2) Adsorption is independent of pressure.

(3) Adsorption is proportional to the pressure.

(4) Adsorption is proportional to the square root of pressure.

SC0088

9. Which one of the following is not a property of physical adsorption **[J- Main (online)2018]**

(1) Unilayer adsorption occurs

(2) Greater the surface area, more the adsorption

(3) Lower the temperature, more the adsorption

(4) Higher the pressure, more the adsorption

SC0089

10. Among the following, the false statement is : **[Jee-main(online)-2019(Jan.)]**

(1) Latex is a colloidal solution of rubber particles which are positively charged

(2) Tyndall effect can be used to distinguish between a colloidal solution and a true solution.

(3) It is possible to cause artificial rain by throwing electrified sand carrying charge opposite to the one on clouds from an aeroplane.

(4) Lyophilic sol can be coagulated by adding an electrolyte.

SC0090

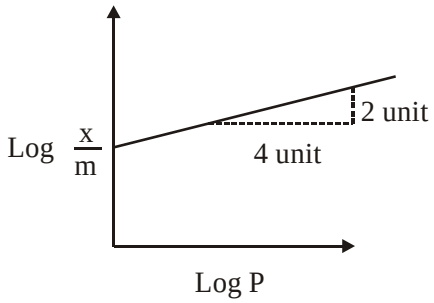
11. An example of solid sol is : **[Jee-main(online)-2019(Jan.)]**

(1) Butter (2) Gem stones (3) Paint (4) Hair cream

SC0091

12. Adsorption of a gas follows Freundlich adsorption isotherm. In the given plot, x is the mass of the gas adsorbed on mass m of the adsorbent at pressure p. $\frac{x}{m}$ is proportional to

[Jee-main(online)-2019(Jan.)]



(1) $P^{1/4}$ (2) P^2 (3) P (4) $P^{1/2}$

SC0092

13. Haemoglobin and gold sol are examples of : **[Jee-main(online)-2019(Jan.)]**

(1) negatively charged sols
(2) positively charged sols]
(3) negatively and positively charged sols, respectively
(4) positively and negatively charged sols, respectively

SC0093

14. Among the colloids cheese (C), milk (M) and smoke (S), the correct combination of the dispersed phase and dispersion medium, respectively is :- **[Jee-main(online)-2019(Jan.)]**

(1) C : solid in liquid; M : solid in liquid ; S : solid in gas
(2) C : solid in liquid; M : liquid in liquid ; S : gas in solid
(3) C : liquid in solid; M : liquid in solid ; S : solid in gas
(4) C : liquid in solid; M : liquid in liquid ; S : solid in gas

SC0094

15. Peptization is a : **[Jee-main(online)-2019(April)]**

(1) process of converting a colloidal solution into precipitate
(2) process of converting precipitate into colloidal solution
(3) process of converting soluble particles to form colloidal solution
(4) process of bringing colloidal molecule into solution

SC0095

16. Among the following, the INCORRECT statement about colloids is :

(1) They can scatter light **[Jee-main(online)-2019(April)]**
(2) They are larger than small molecules and have high molar mass
(3) The range of diameters of colloidal particles is between 1 and 1000 nm
(4) The osmotic pressure of a colloidal solution is of higher order than the true solution at the same concentration

SC0096

17. A gas undergoes physical adsorption on a surface and follows the given Freundlich adsorption isotherm equation

$$\frac{x}{m} = kp^{0.5}$$

Adsorption of the gas increases with : **[Jee-main(online)-2019(April)]**

(1) Decrease in p and decrease in T
(2) Increase in p and increase in T
(3) Increase in p and decrease in T
(4) Decrease in p and increase in T

SC0097

18. The aerosol is a kind of colloid in which : **[Jee-main(online)-2019(April)]**

(1) gas is dispersed in solid (2) solid is dispersed in gas
(3) liquid is dispersed in water (4) gas is dispersed in liquid

SC0098

19. 10 mL of 1mM surfactant solution forms a monolayer covering 0.24 cm^2 on a polar substrate. If the polar head is approximated as cube, what is its edge length?

[Jee-main(online)-2019(April)]

(1) 2.0 pm (2) 2.0 nm (3) 1.0 pm (4) 0.1 nm

SC0099

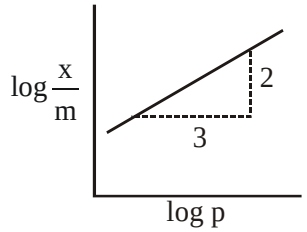
20. 0.27 g of a long chain fatty acid was dissolved in 100 cm^3 of hexane. 10 mL of this solution was added dropwise to the surface of water in a round watch glass. Hexane evaporates and a monolayer is formed. The distance from edge to centre of the watch glass is 10 cm. What is the height of the monolayer?

[Density of fatty acid = 0.9 g cm^{-3}, $\pi = 3$] **[Jee-main(online)-2019(April)]**

(1) 10^{-8} m (2) 10^{-6} m (3) 10^{-4} m (4) 10^{-2} m

SC0100

21. Adsorption of a gas follows Freundlich adsorption isotherm x is the mass of the gas adsorbed on mass m of the adsorbent. The plot of $\log \frac{x}{m}$ versus log p is shown in the given graph. $\frac{x}{m}$ is proportional to : **[Jee-main(online)-2019(April)]**



(1) $p^{3/2}$ (2) p^3 (3) $p^{2/3}$ (4) p^2

SC0101

22. The correct option among the following is : **[Jee-main(online)-2019(April)]**

(1) Colloidal particles in lyophobic sols can be precipiated by electrophoresis.
(2) Brownian motion in colloidal solution is faster the viscosity of the solution is very high.
(3) Colloidal medicines are more effective because they have small surface area.
(4) Addition of alum to water makes it unfit for drinking.

SC0102

23. Match the following : **[JEE MAINS Online-2020]**

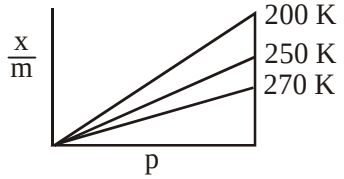
(i) Foam	(a) smoke
(ii) Gel	(b) cell fluid
(iii) Aerosol	(c) jellies
(iv) Emulsion	(d) rubber
	(e) froth
	(f) milk

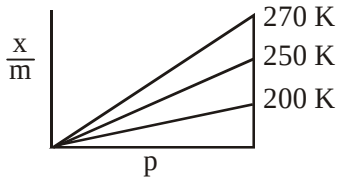
(1) (i)-(b), (ii)-(c), (iii)-(e), (iv)-(d) (2) (i)-(d), (ii)-(b), (iii)-(e), (iv)-(f)

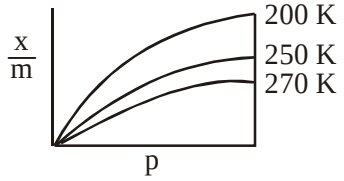
(3) (i)-(e), (ii)-(c), (iii)-(a), (iv)-(f) (4) (i)-(d), (ii)-(b), (iii)-(a), (iv)-(e)

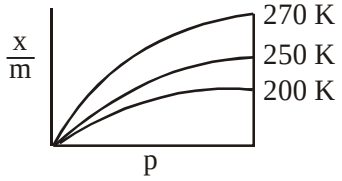
SC0103

24. Adsorption of a gas follows Freundlich adsorption isotherm. If x is the mass of the gas adsorbed on mass m of the adsorbent, the correct plot of $\frac{x}{m}$ versus p is : **[JEE MAINS Online-2020]**

(1) 

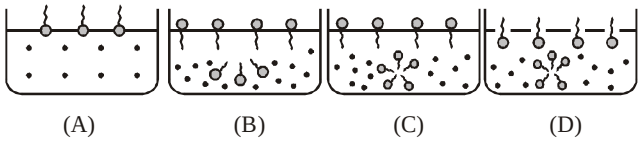
(2) 

(3) 

(4) 

SC0104

25. Identify the correct molecular picture showing that happens at the critical micellar concentration (CMC) of an aqueous solution of a surfactant (○ polar head; ∽ non-polar tail; • water).



[JEE MAINS Online-2020]

(1) (B) (2) (A) (3) (D) (4) (C)

SC0105

26. For Freundlich adsorption isotherm, a plot of log (x/m) (y-axis) and log p (x-axis) gives a straight line. The intercept and slope for the line is 0.4771 and 2, respectively. The mass of gas, adsorbed per gram of adsorbent if the initial pressure is 0.04 atm, is_ _ _ _ _ _ $\times 10^{-4}$g.

(log 3 = 0.4771) **[JEE MAINS Online-2020]**

SC0106

27. The size of a raw mango shrinks to a much smaller size when kept in a concentrated salt solution. Which one of the following processes can explain this ? **[JEE MAINS Online-2020]**

(1) Diffusion (2) Dialysis (3) Osmosis (4) Reverse osmosis

SC0107

28. Amongst the following statements regarding adsorption, those that are valid are :

(a) ΔH becomes less negative as adsorption proceeds. **[JEE MAINS Online-2020]**

(b) On a given adsorbent, ammonia is adsorbed more than nitrogen gas.

(c) On adsorption, the residual force acting along the surface of the adsorbent increases.

(d) With increase in temperature, the equilibrium concentration of adsorbate increases.

(1) (b) and (c) (2) (a) and (b) (3) (d) and (a) (4) (c) and (d)

SC0108

29. The mass of gas adsorbed, x, per unit mass of adsorbate, m, was measured at various pressures, p. A graph between $\log \frac{x}{m}$ and log p gives a straight line with slope equal to 2 and the intercept equal to 0.4771. The value of $\frac{x}{m}$ at a pressure of 4 atm is : (Given log 3 = 0.4771)

[JEE MAINS Online-2020]

SC0109

EXERCISE # J-ADVANCED

1. Among the following, the surfactant that will from micelles in aqueous solution at the lowest molar concentration at ambient conditions is **[JEE 2008]**

(A) $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$

(B) $CH_3(CH_2)_{11}OSO_3^-Na^+$

(C) $CH_3(CH_2)_6COO^-Na^+$

(D) $CH_3(CH_2)_{11}N^+(CH_3)_3Br^-$

SC0110

2. Among the electrolytes Na_2SO_4, $CaCl_2$, $Al_2(SO_4)_3$ and NH_4Cl, the most effective coagulation agent for Sb_2S_3 sol is **[JEE 2009]**

(A) Na_2SO_4

(B) $CaCl_2$

(C) $Al_2(SO_4)_3$

(D) NH_4Cl

SC0111

3. The correct statement(s) pertaining to the adsorption of a gas on a solid surface is (are) -

(A) Adsorption is always exothermic **[JEE 2011]**

(B) Physisorption may transform into chemisorption at high temperature

(C) Physisorption increases with increasing temperature but chemisorption decreases with increasing temperature

(D) Chemisorption is more exothermic than physisorption, however it is very slow due to higher energy of activation

SC0112

4. Choose the correct reason(s) for the stability of the **lyophobic** colloidal particle. **[JEE 2012]**

(A) Preferential adsorption of ions on their surface from the solution

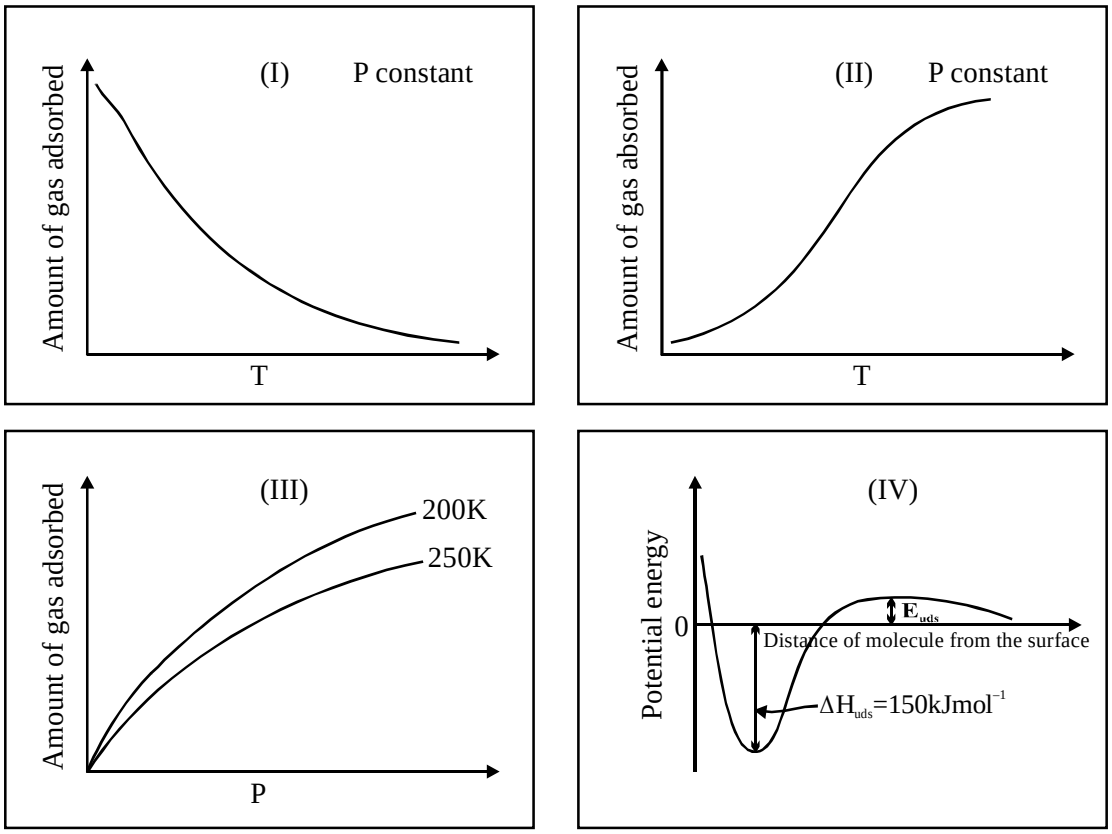
(B) Preferential adsorption of solvent on their surface from the solution

(C) Attraction between different particles having opposite charges on their surface

(D) Potential difference between the fixed layer and the diffused layer of opposite charges around the colloidal particles

SC0113

5. 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 ? **[JEE 2012]**



(A) **I** is physisorption and **II** is chemisorption
(B) **I** is physisorption and **III** is chemisorption
(C) **IV** is chemisorption and **II** is chemisorption
(D) **IV** is chemisorption and **III** is chemisorption

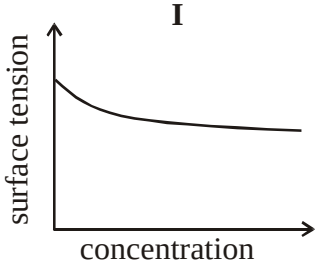
SC0114

6. Methylene blue, from its aqueous solution, is adsorbed on activated charcoal at 25ºC. For this process, the correct statement is - **[J. Adv. 2013]**
(A) The adsorption requires activation at 25ºC
(B) The adsorption is accompanied by a decrease in enthalpy
(C) The adsorption increases with increase of temperature
(D) The adsorption is irreversible

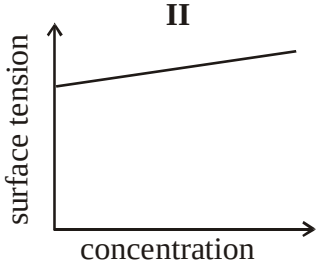
SC0115

7. The qualitative sketches I , II and III given below show the variation of surface tension with molar concentration of three different aqueous solutions of KCl, CH_3OH and $CH_3(CH_2)_{11}OSO_3^-Na^+$ at room temperature. The correct assignment of the sketches is - **[J. Adv. 2016]**

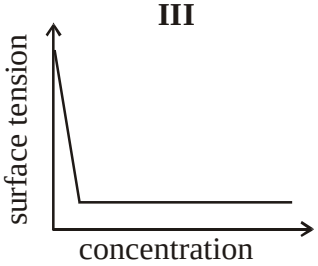
I



II



III



(A) **I :** KCl **II :** CH_3OH **III :** $CH_3(CH_2)_{11}OSO_3^-Na^+$

(B) **I :** $CH_3(CH_2)_{11}OSO_3^-Na^+$ **II :** CH_3OH **III :** KCl

(C) **I :** KCl **II :** $CH_3(CH_2)_{11}OSO_3^-Na^+$ **III :** CH_3OH

(D) **I :** CH_3OH **II :** KCl **III :** $CH_3(CH_2)_{11}OSO_3^-Na^+$

SC0116

8. The correct statement(s) about surface properties is (are) **[JEE 2017]**

(A) Cloud is an emulsion type of colloid in which liquid is dispersed phase and gas is dispersion medium

(B) Adsorption is accompanied by decrease in enthalpy and decrease in entropy of the system.

(C) Brownian motion of colloidal particles does not depend on the size of the particles but depends on viscosity of the solution.

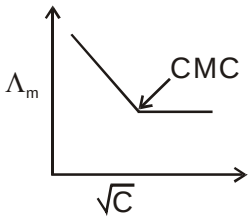
(D) The critical temperatures of ethane and nitrogen and 563 K and 126 K, respectively. The adsorption of ethane will be more than that of nitrogen on same amount of activated charcoal at a given temperature.

SC0117

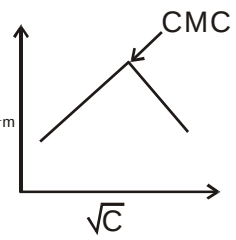
9. Molar conductivity (Λ_m) of aqueous solution of sodium stearate, which behaves as a strong electrolyte, is recorded at varying concentration(c) of sodium stearate. Which one of the following plots provides the correct representation of micelle formation in the solution ?

(Critical micelle concentration (CMC) is marked with an arrow in the figures.) **[JEE 2019]**

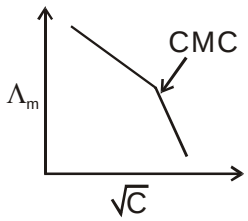
(1)



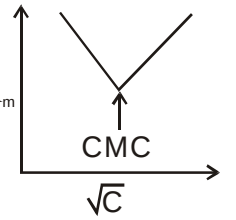
(2)



(3)



(4)



SC0118

ANSWER KEY

EXERCISE-S-I

1.	Ans. (200)	2.	Ans.(0.6)	3.	Ans (1)
4.	Ans.(5)	5.	Ans.(3)	6.	Ans. (30)
7.	Ans.(5)	8.	Ans.(9)	9.	Ans.(600)
10	Ans.(4)				

EXERCISE-S-II

1.	Ans.(3)	2.	Ans. (1)	3.	Ans. (3)
4.	Ans.(2)	5.	Ans. 2.4×10^6 cm^2/gm		
6.	Ans. 4 sec	7.	Ans. (6)	8.	Ans. $\frac{3}{140}$
9.	2.35×10^9	10.	Ans. 10^4 times		

EXERCISE # O-I

1	Ans. (B)	2.	Ans. (B)	3.	Ans. (A)
4.	Ans.(B)	5.	Ans.(B)	6.	Ans.(B)
7.	Ans.(B)	8.	Ans.(C)	9.	Ans.(B)
10.	Ans.(D)	11.	Ans.(A)	12.	Ans.(D)
13.	Ans.(C)	14.	Ans.(B)	15	Ans.(C)
16.	Ans.(A)	17.	Ans.(B)	18.	Ans.(A)
19.	Ans.(B)	20.	Ans.(C)	21	Ans.(B)
22	Ans.(C)	23.	Ans.(B)	24.	Ans.(B)
25.	Ans. (D)	26.	Ans.(C)	27.	Ans.(D)
28.	Ans.(D)	29	Ans.(B)	30.	Ans.(B)
31	Ans.(C)	32.	Ans.(B)	33.	Ans.(C)
34.	Ans.(A)	35	Ans.(B)	36.	Ans.(D)
37.	Ans.(B)	38.	Ans.(B)	39.	Ans.(A)
40.	Ans.(C)				

EXERCISE # O-II

1	Ans.(A,B,D)	2.	Ans.(A,B,D)	3.	Ans.(A, B)
4.	Ans.(A,B,D)	5.	Ans.(B,C,D)	6.	Ans.(A, B)
7.	Ans.(B,C,D)	8.	Ans.(D)	9.	Ans.(C)
10.	Ans.(B)	11.	Ans.(A, C)	12.	Ans.(A)
13.	Ans.(D)	14.	Ans.(B, D)	15.	Ans.(A)
16.	Ans.(A)	17.	Ans.(A)	18.	Ans. (C)
19.	Ans.(B)	20.	Ans.(C)		

EXERCISE # J-MAIN

1.	Ans.(2)	2.	Ans. (4)	3.	Ans. (2)
4.	Ans.(2)	5.	Ans. (4)	6.	Ans. (2)
7.	Ans. (2)	8.	Ans. (4)	9.	Ans. (1)
10.	Ans.(1)	11.	Ans.(2)	12.	Ans.(4)
13.	Ans.(4)	14.	Ans.(4)	15.	Ans.(2)
16.	Ans.(4)	17.	Ans.(3)	18.	Ans. (2)
19.	Ans.(1)	20.	Ans.(2)	21.	Ans.(3)
22.	Ans.(1)	23.	Ans.(3)	24.	Ans.(3)
25.	Ans.(3)	26.	Ans.(48.00)	27.	Ans.(3)
28.	Ans.(2)	29.	Ans.(6.00)		

EXERCISE # J-ADVANCED

1.	Ans.(A)	2.	Ans.(C)	3.	Ans.(A, B, D)
4.	Ans.(A,D)	5.	Ans.(A,C)	6.	Ans.(B)
7.	Ans.(D)	8.	Ans.(B,D)	9.	Ans.(3)