Unit
5

Surface Chemistry

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Objectives

- Surface chemistry deals with phenomena that occur at the surfaces or interfaces.
- In this Unit, we will be studying some important features of surface chemistry such as
- adsorption, catalysis and colloids including emulsions and gels.

Adsorption

- ***The accumulation of molecular species at the surface rather than in the bulk of a solid or liquid is termed adsorption*.**
- 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.

Adsorbate & adsorbent

- The molecular species or substance, which concentrates or accumulates at the surface is termed **adsorbate**
- **and the material on the** surface of which the adsorption takes place is called **adsorbent.**
- For e.g. Adsorption of **acetic acid** on **charcoal**.

Desorption & *sorption*

- The process of removing an adsorbed substance from a surface on which it is adsorbed is called **desorption.**
- *Both adsorption and absorption can take place simultaneously also.*
- *The term **sorption** is used to describe both the processes.*

Distinction between Adsorption and Absorption

Adsorption	Absorption
• It is a surface phenomenon	• It is a bulk phenomenon

Mechanism of Adsorption

- Inside the adsorbent all the forces acting between the particles are mutually balanced but on the surface they possess unbalanced or residual attractive forces.
- These forces of the adsorbent are responsible for attracting the adsorbate particles on its surface.
- heat of adsorption.

Mechanism of Adsorption

- ΔH of adsorption is always negative.
- ΔS is negative.
- 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.

ΔG value for system at Equilibrium

- As the adsorption proceeds, ΔH becomes less and less negative ultimately ΔH becomes equal to TΔS and **ΔG becomes zero**.

- At this state equilibrium is attained.

Types of Adsorption

- There are mainly two types of adsorption of gases on solids.

1. **Physical adsorption or physisorption.**

2. **Chemical adsorption or chemisorption.**

Comparison of Physisorption and Chemisorption

Physisorption	Chemisorption
1 . It arises because of van der Waals’ forces.	**1. It is caused by chemical bond** formation.
2. It is not specific in nature.	**2. It is highly specific in nature.**
3. It is reversible in nature.	**3. It is irreversible.**
4. It depends on the nature of gas. More easily liquefiable gases are adsorbed readily.	**4. It also depends on the nature** of gas. Gases which can react with the adsorbent show chemisorption.
5. Enthalpy of adsorption is low (20-40 kJ mol–1)in this case.	**5. Enthalpy of adsorption is high** (80-240 kJ mol–1) in this case.

Comparison of Physisorption and Chemisorption

Physisorption	Chemisorption
6. **Low temperature is favourable** for adsorption. It decreases with increase of temperature.	**6. High temperature is favourable** for adsorption. It increases with the increase of temperature.
7. No appreciable activation energy is needed.	**7. High activation energy is** sometimes needed.
8. It depends on the surface area. It increases with an increase of surface area.	**8. It also depends on the surface** area. It too increases with an increase of surface area.
9. It results into multimolecular layers on adsorbent surface under high pressure.	**9. It results into unimolecular** layer.

Adsorption Isotherms

- The variation in the amount of gas adsorbed by the adsorbent with pressure at constant temperature can be expressed by means of a curve termed as **adsorption isotherm.**

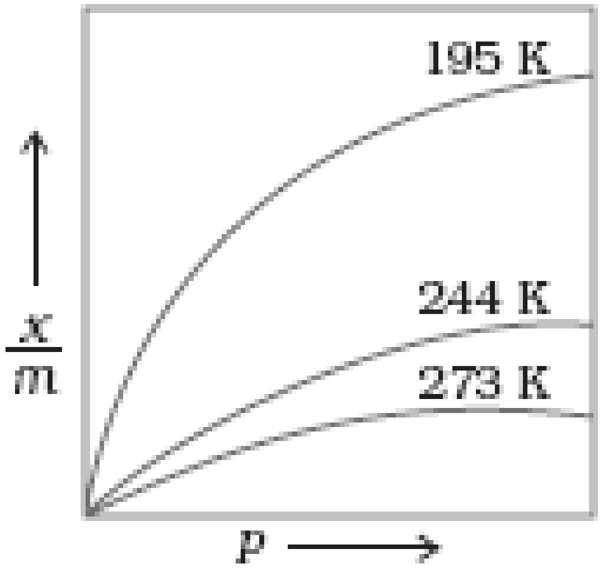


Fig. 5.1: Adsorption isotherm

Freundlich adsorption isotherm:

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

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

Freundlich adsorption isotherm

- Taking logarithm of equation. we get

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

The validity of Freundlich isotherm can be verified by plotting log *x/m* on *y-axis (ordinate)* and log *P on x-axis (abscissa).*

If it comes to be a straight line, the Freundlich isotherm is valid, otherwise not (Fig. 5.2)

Freundlich adsorption isotherm(Graph)

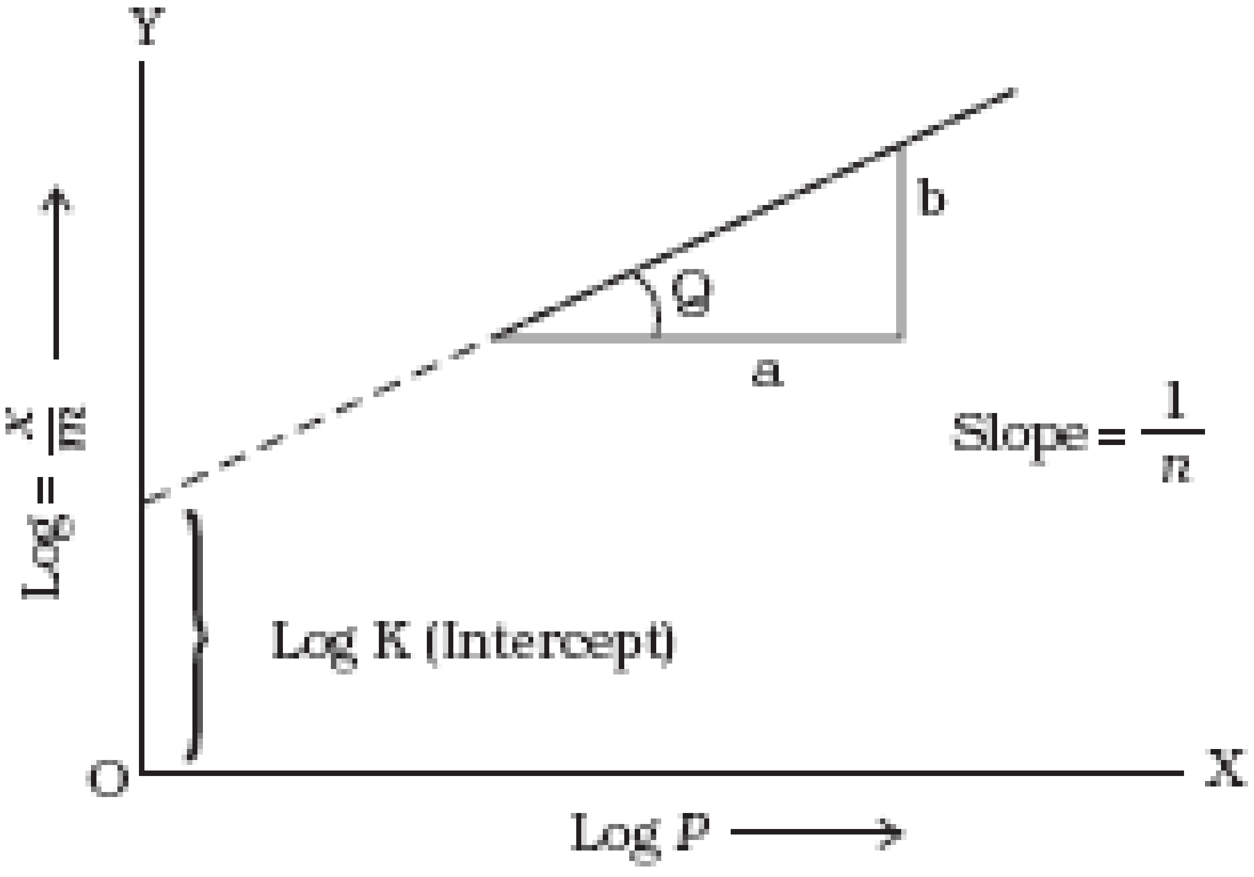


Fig. 5.2: Freundlich isotherm

Values of k and n

- The slope of the straight line gives the value of **1/*n***
- *The intercept* on the *y-axis gives the value of* ***log k***.
- Freundlich isotherm explains the behaviour of adsorption in an approximate manner.
- The factor 1/*n can have values between 0 and 1* (probable range 0.1 to 0.5).
- Thus, equation (5.2) holds good over a limited range of pressure.

Freundlich isotherm fails at high pressure

- When $1/n = 0$, x/m = constant, the adsorption is independent of pressure.
- When $1/n = 1$, $x/m = k\,P$, *i.e.* $x/m \propto P$, *the adsorption varies directly* with pressure.
- Both the conditions are supported by experimental results.
- The experimental isotherms always seem to approach saturation at high pressure.
- This cannot be explained by Freundlich isotherm.
- Thus, it **fails** at **high pressure**.

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.

- The following observations have been made in the case of adsorption from solution phase:

Adsorption from solution phase: ………observations

(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.

Freundlich isotherm for solution phase

- 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.,

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

Freundlich isotherm for solution phase

- (*C is the equilibrium concentration, i.e., when adsorption is complete).*
- On taking logarithm of the above equation, we have

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

Applications of Adsorption

- (i) *Production of high vacuum:*
- (ii) *Gas masks*
- (iii) *Control of humidity:*
- (iv)*Removal of colouring matter from solutions:*
- (v) *Heterogeneous catalysis:*
- (vi) *Separation of inert gases:*
- (vii) *In curing diseases:*
- (viii) *Froth floatation process:*
- (ix) *Adsorption indicators:*
- (x) *Chromatographic analysis:*

Catalysis

- Potassium chlorate, when heated strongly decomposes slowly giving dioxygen.
- The decomposition occurs in the temperature range of 653-873K.
  - $2KClO_3 \rightarrow 2KCl + 3O_2$
- However, when a little of manganese dioxide is added, the decomposition takes place at a considerably lower temperature range, i.e., 473-633K and also at a much accelerated rate.

Catalysis

- The added manganese dioxide remains unchanged with respect to its mass and composition.
- 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.

Catalysts & catalysis

- Substances, which alter 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.

Promoters and poisons

- Promoters are substances that enhance the activity of a catalyst while
- poisons decrease the activity of a catalyst.
- For example, in Haber’s process for manufacture of ammonia, molybdenum acts as a promoter for iron which is used as a catalyst.

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

Homogeneous and Heterogeneous Catalysis

(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.

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

(iii) Hydrolysis of sugar is catalysed by H+ ions furnished by sulphuric acid.

$$\underset{\text{Solution}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{H_2SO_4(l)} \underbrace{\underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{Fructose}}{C_6H_{12}O_6(aq)}}_{\text{Solution}}$$

(b) *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.

Adsorption Theory of Heterogeneous Catalysis

- 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:

Mechanism

- (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 (Fig. 5.3).
- (iv) Desorption of reaction products from the catalyst surface, and thereby, making the surface available again for more reaction to occur.

Mechanism

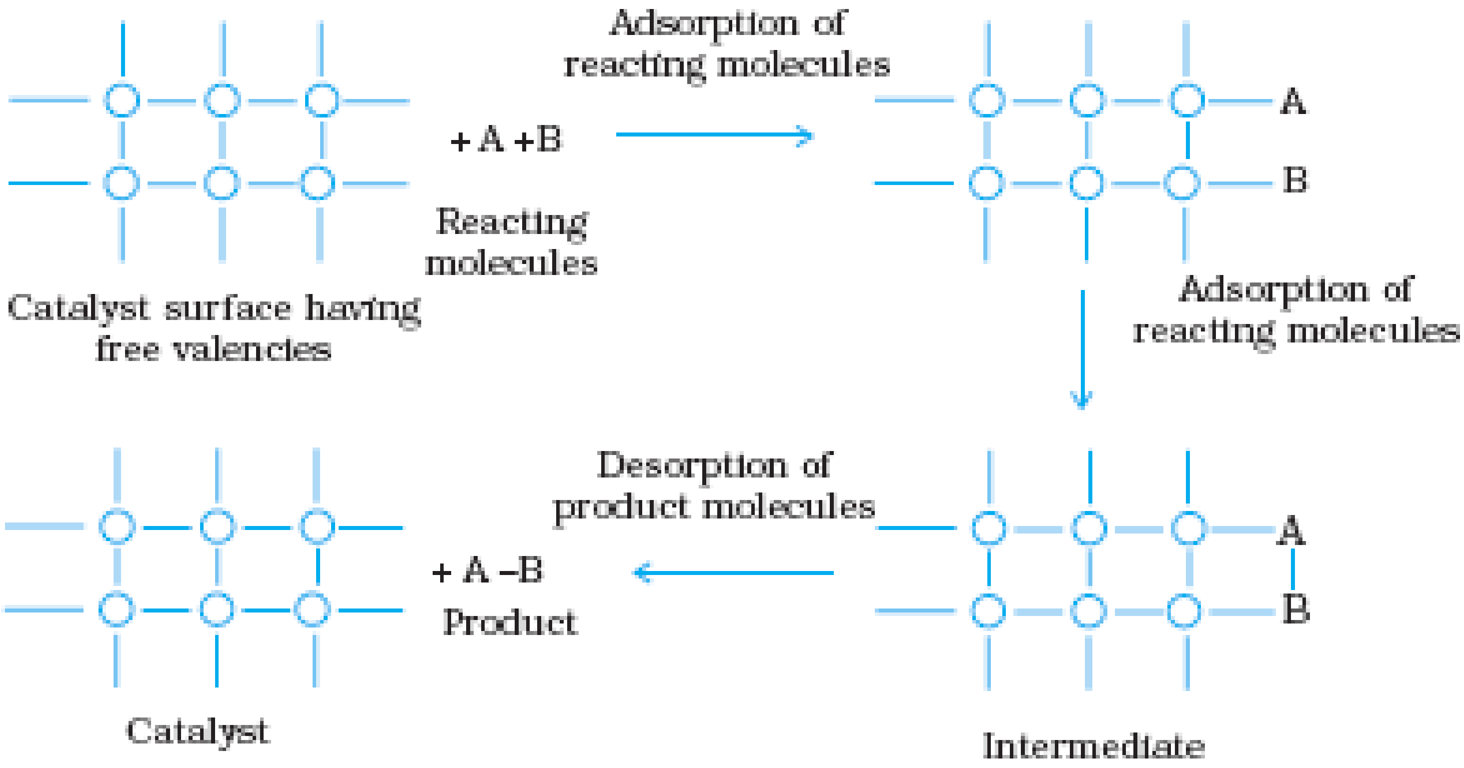
(v) Diffusion of reaction products away from the catalyst’s surface. The surface of the catalyst unlike the inner part of the bulk, has free valencies which provide the seat for chemical forces of attraction.

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

Fig. 5.3



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.

Important features of solid catalysts

(a) Activity & (b) Selectivity

- ***(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.

Important features of solid catalysts

(a) Activity

- 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

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

(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.

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

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

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

(b) Selectivity

- 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.

- It means that a substance which acts as a catalyst in one reaction may fail to catalyse another reaction.

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.

Zeolites

- 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

- 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.

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.
- The enzymes are, **thus**, termed as **biochemical catalysts and the phenomenon is known as biochemical catalysis.**

Examples of enzyme-catalysed reactions:

(i) *Inversion of cane sugar:*

- *The invertase enzyme converts cane sugar* into glucose and fructose.

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

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

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

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

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

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

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

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

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

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

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

(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.

Some Enzymatic Reactions

Enzyme	Source	Enzymatic reaction
Invertase	Yeast	Sucrose → Glucose and fructose
Zymase	Yeast	Glucose → Ethyl alcohol and carbon dioxide
Diastase	Malt	Starch → Maltose
Maltase	Yeast	Maltose → Glucose
Urease	Soyabean	Urea → Ammonia and carbon dioxide
Pepsin	Stomach	Proteins → Amino acids

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:*
- (ii) *Highly specific nature:*
- (iii) *Highly active under optimum temperature:*
- (iv) *Highly active under optimum pH:*

Characteristics of enzyme catalysis

- (v) *Increasing activity in presence of activators and co-enzymes:*
- (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.

Mechanism of enzyme catalysis

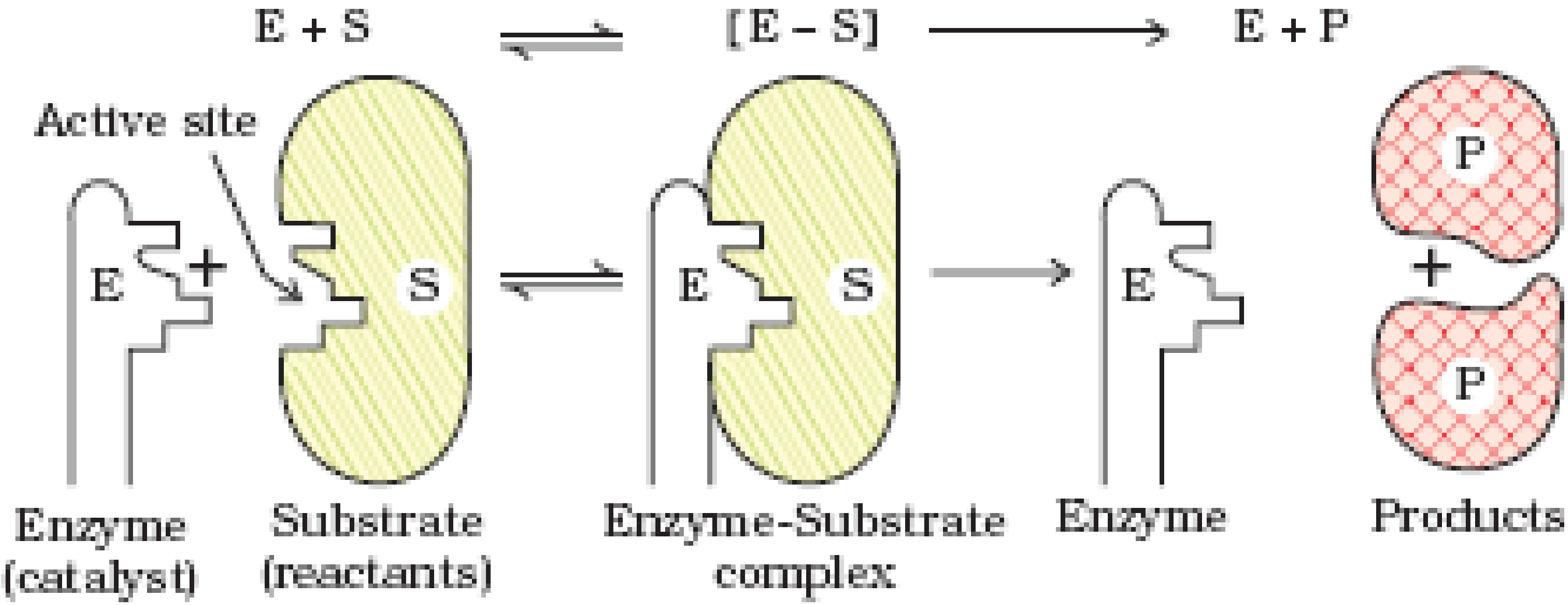
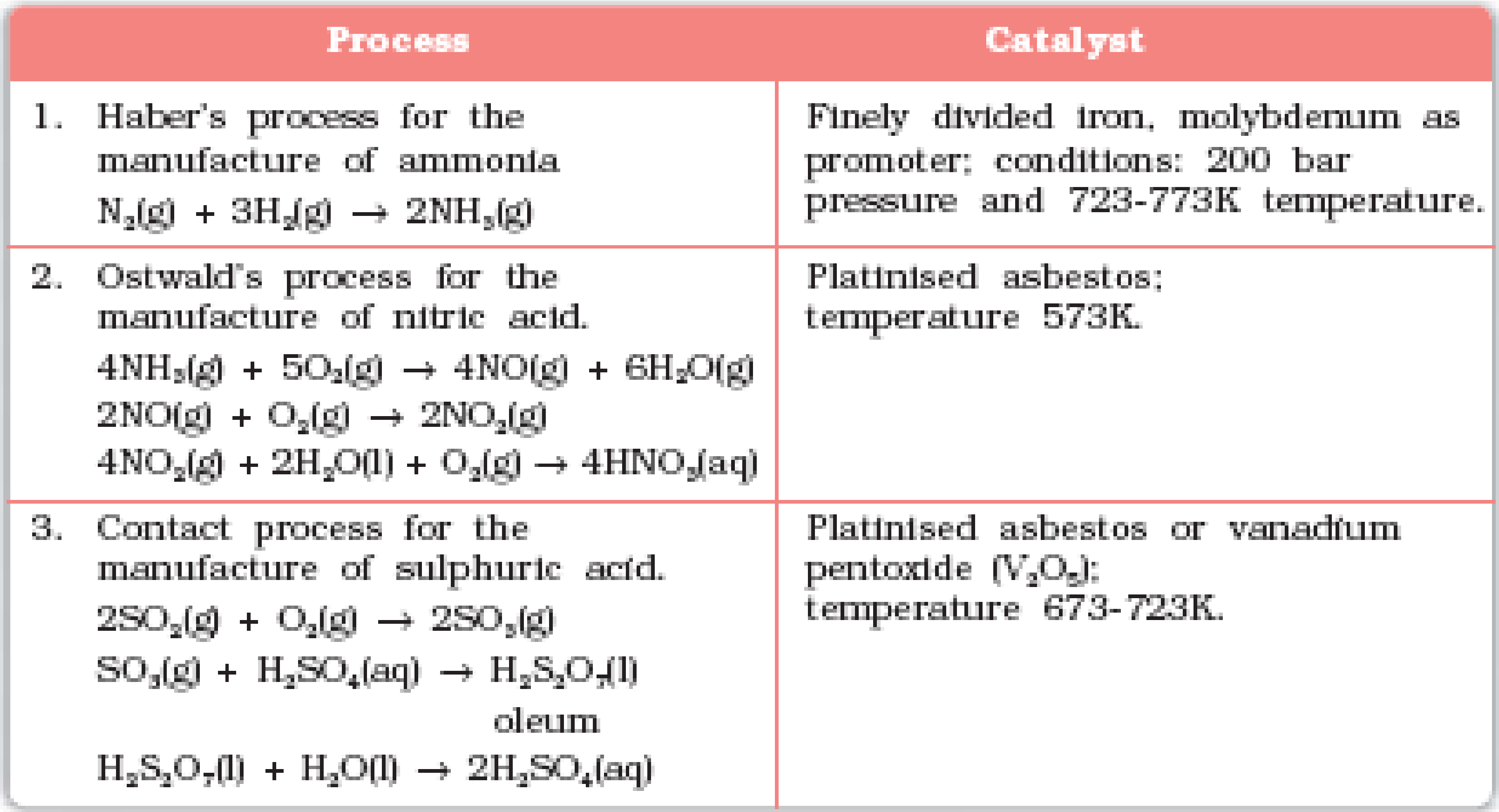


Fig. 5.4: Mechanism of enzyme catalysed reaction

Mechanism of enzyme catalysis

- Thus, the enzyme-catalysed reactions may be considered to proceed in two steps.
- **Step 1: Binding of enzyme to substrate to form an activated complex.**
  - $E + S \rightarrow ES^*$
- **Step 2: Decomposition of the activated complex to form product.**
  - $ES^* \rightarrow E + P$

Catalysts in Industry



Process	Catalyst
1. Haber's process for the manufacture of ammonia $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	Finely divided iron, molybdenum as promoter; conditions: 200 bar pressure and 723-773K temperature.
2. Ostwald's process for the manufacture of nitric acid. $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$	Platinised asbestos; temperature 573K.
3. Contact process for the manufacture of sulphuric acid. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $SO_3(g) + H_2SO_4(aq) \rightarrow \underset{\text{oleum}}{H_2S_2O_7(l)}$ $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(aq)$	Platinised asbestos or vanadium pentoxide (V_2O_5); temperature 673-723K.

True Solution	**Colloids**	**Suspension**

Characteristics of Suspension, Colloid and Solution

	Properties	Suspension	Colloid	Solution
1.	Particle size	>100nm	1-100nm	<1nm
2.	Separation 1)ordinary filtration 2) ultra filtration	possible possible	not possible possible	not possible not possible
3.	Settling	Settles under gravity	Settles on Centrifugation	Does not settle
4.	Appearance	opaque	Generally clear	clear
5.	Diffusion	Not possible	Diffuses slowly	Diffuses rapidly
6.	Brownian motion	shows	shows	Not observable
7.	Tyndall effect	shows	shows	Not observable

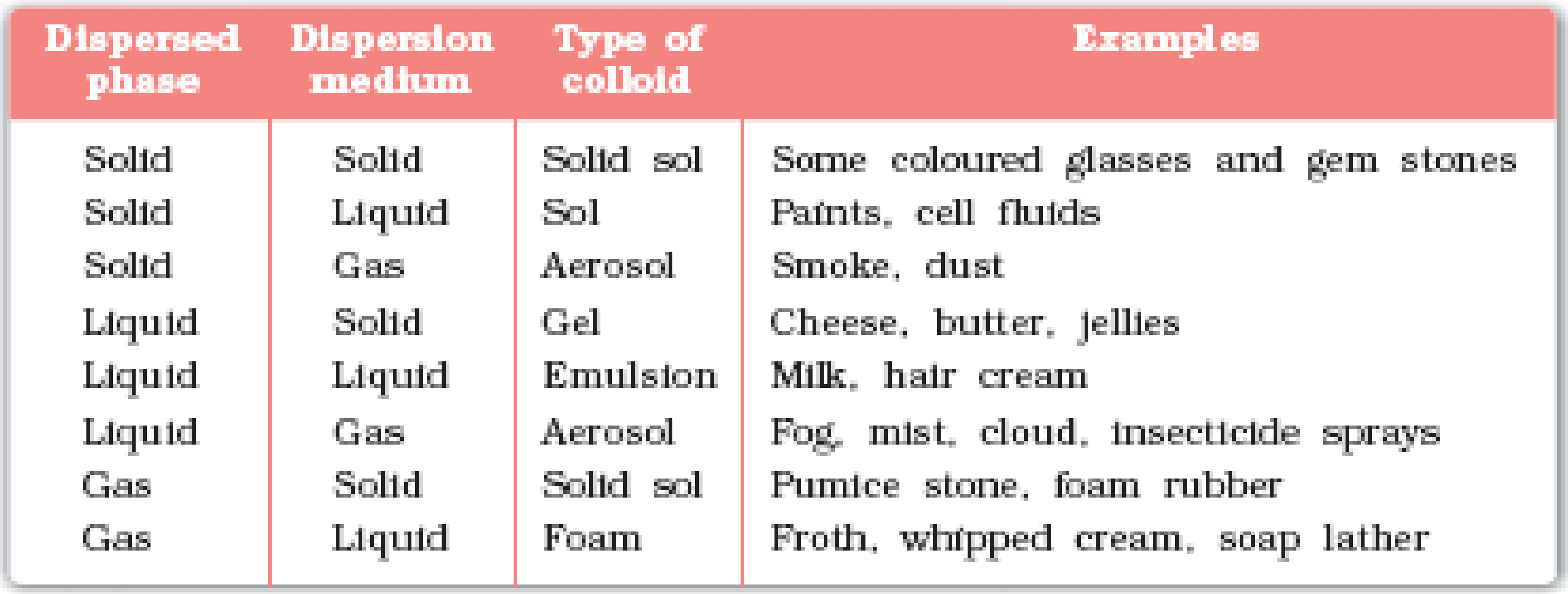
Colloids

- Between the two extremes of suspensions and solutions we come across a large group of systems called colloidal dispersions or simply **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.
- The essential difference between a solution and a colloid is that of particle size.
- Their range of diameters is between 1 and 100 nm.

Classification of Colloids

- Colloids are classified on the basis of the following criteria:
- (i) Physical state of dispersed phase and dispersion medium
- (ii) Nature of interaction between dispersed phase and dispersion medium
- (iii) Type of particles of the dispersed phase.

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

Sols, gels and **emulsions**

- Out of the various types of colloids given in, the table, most common are **sols (solids in liquids), gels** (liquids in solids) and **emulsions (liquids in liquids).**

- Further, it may be mentioned that if the dispersion medium is water, the sol is called aquasol or hydrosol and if the dispersion medium is alcohol, it is called alcosol and so on.

Lyophilic and lyophobic sols

- Depending upon the nature of interaction between the dispersed phase and the dispersion medium, colloidal sols are divided into two categories,
- namely, **lyophilic (solvent attracting) and lyophobic (solvent repelling).**
- If water is the dispersion medium, the terms used are hydrophilic and hydrophobic.

Difference between Lyophilic and lyophobic sols

Property	Lyophilic Colloids	Lyophobic Colloids
Ease of preparation	They are prepared by direct mixing.	They are prepared by special method
Reversibility	The are reversible	They are irreversible
Particles Nature	The particles are big in size & are true molecule.	The particles are aggregate of many molecules.
Visibility	The particles can not be seen by ultra microscope.	The particles can be seen by ultra microscope.
Stability	It is stable	It is less stable

Difference between Lyophilic and lyophobic sols

Property	Lyophilic Colloids	Lyophobic Colloids
Action of electrolytes	They are not easily precipitated by small amount of electrodes.	They are easily precipitated
Charge on particles	They do not carry any charge.	They are having specific charge.
Hydration	They are easily hydrated	They are not hydrated.
viscosity	The viscosity of solutions is much higher than that of the dispersion medium.	The viscosity of solutions are nearly same as dispersion medium
Tyndall Effect	They do not show Tyndall effect.	They show Tyndall effect.
Examples	gum, gelatine, starch, rubber etc in water	$Fe(OH)_{3,}$

Classification of Colloids based on Type of Particles of the Dispersed Phase

- Depending upon the type of the particles of the dispersed phase, colloids are classified as:

1. Multimolecular,
2. Macromolecular and
3. 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 S_8 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.**

(iii) *Associated colloids* *(Micelles):*

- 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.
- For soaps, the CMC is 10^{-4} to 10^{-3} mol L^{-1}. These colloids have both lyophobic and lyophilic parts.
- Micelles may contain as many as 100 molecules or more.

Mechanism of micelle formation

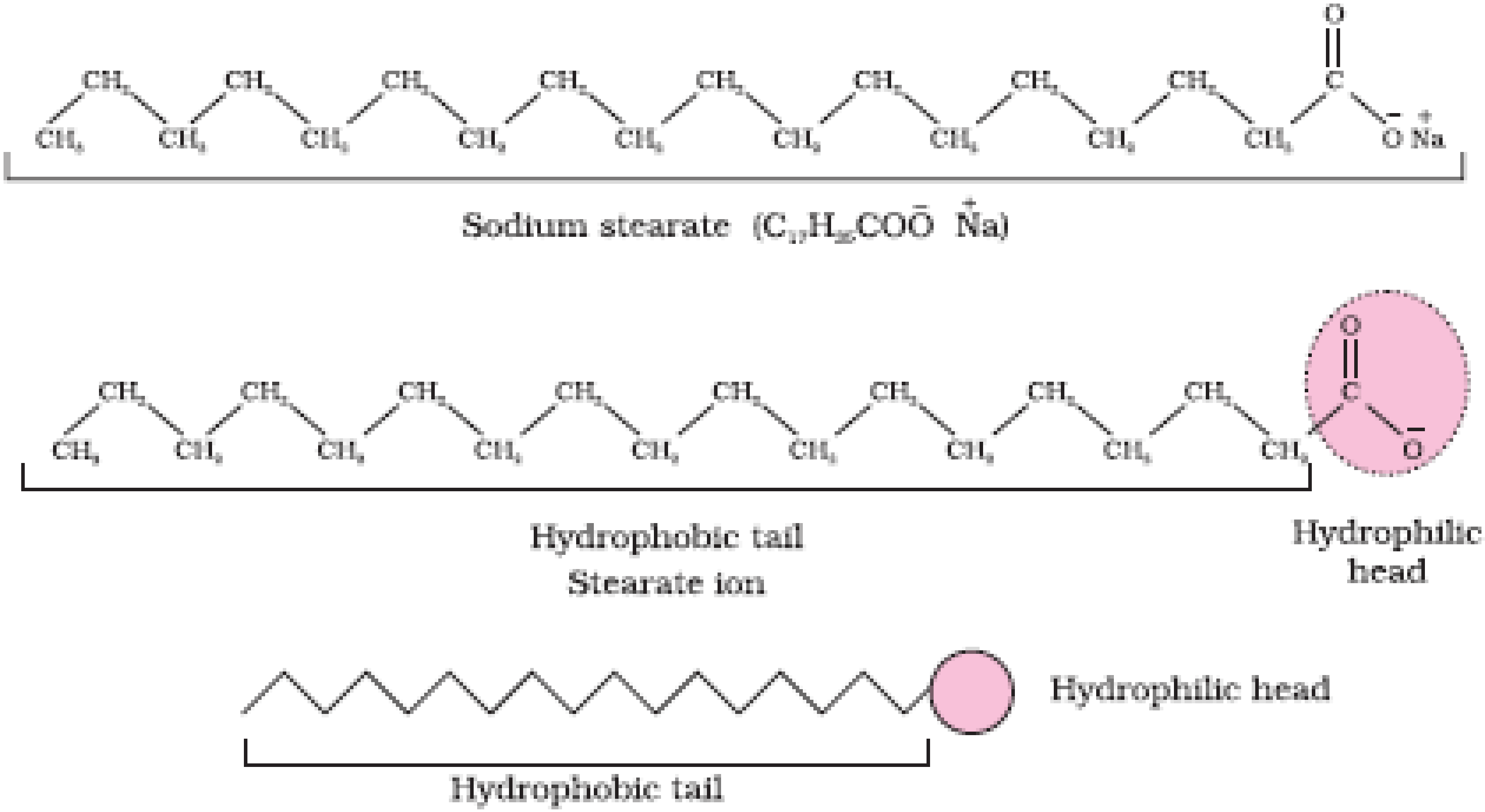
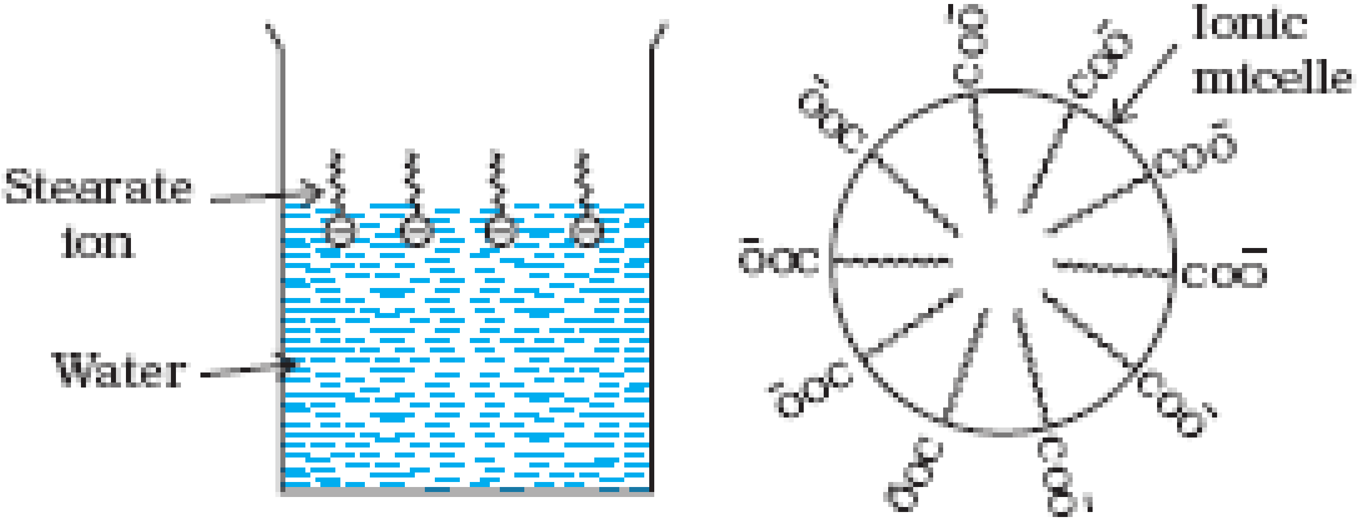


Fig. 5.5: Hydrophobic and hydrophilic parts of stearate ion

Mechanism of micelle formation



(a) (b)

Fig. 5.6: (a) Arrangement of stearate ions on the surface of water at low concentrations of soap
(b) Arrangement of stearate ions inside the bulk of water (ionic micelle) at critical micelle concentrations of soap

Cleansing action of soaps

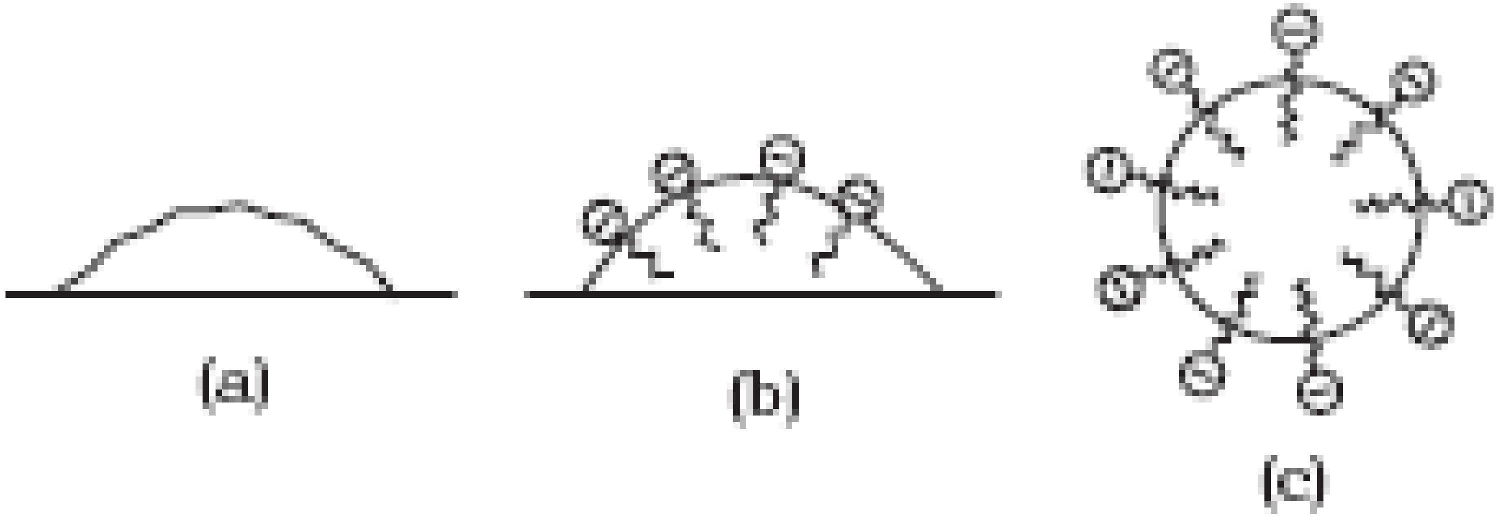


Fig. 5.7: *(a) Grease on cloth (b) Stearate ions arranging around the grease droplet and (c) Grease droplet surrounded by stearate ions (micelle formed)*

Preparation of Colloids

(a) Chemical methods

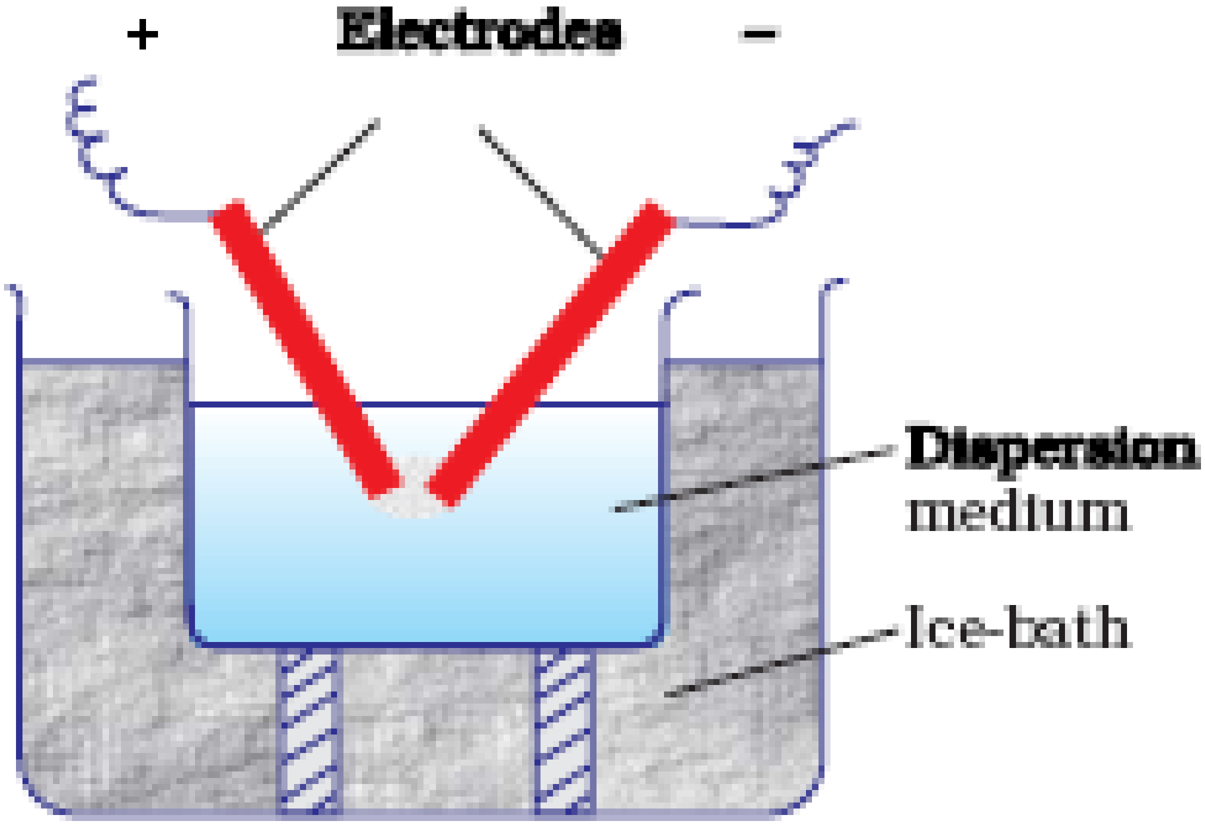
$$As_2O_3 + 3H_2S \xrightarrow{\text{Double decomposition}} As_2S_3(\text{sol}) + 3H_2O$$

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

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

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

(b) *Electrical disintegration or Bredig's Arc method*



(c) *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.**

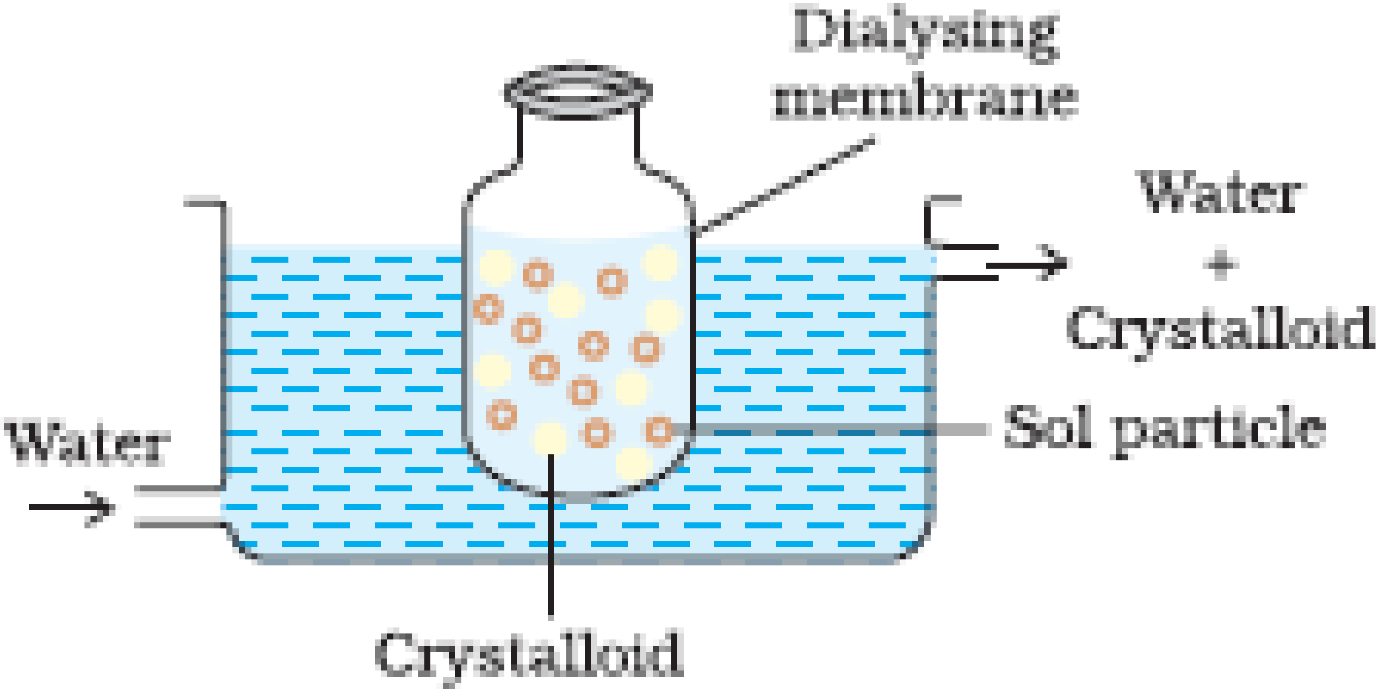
- This method is applied, generally, to convert a freshly prepared precipitate into a colloidal sol.

Purification of Colloidal Solutions

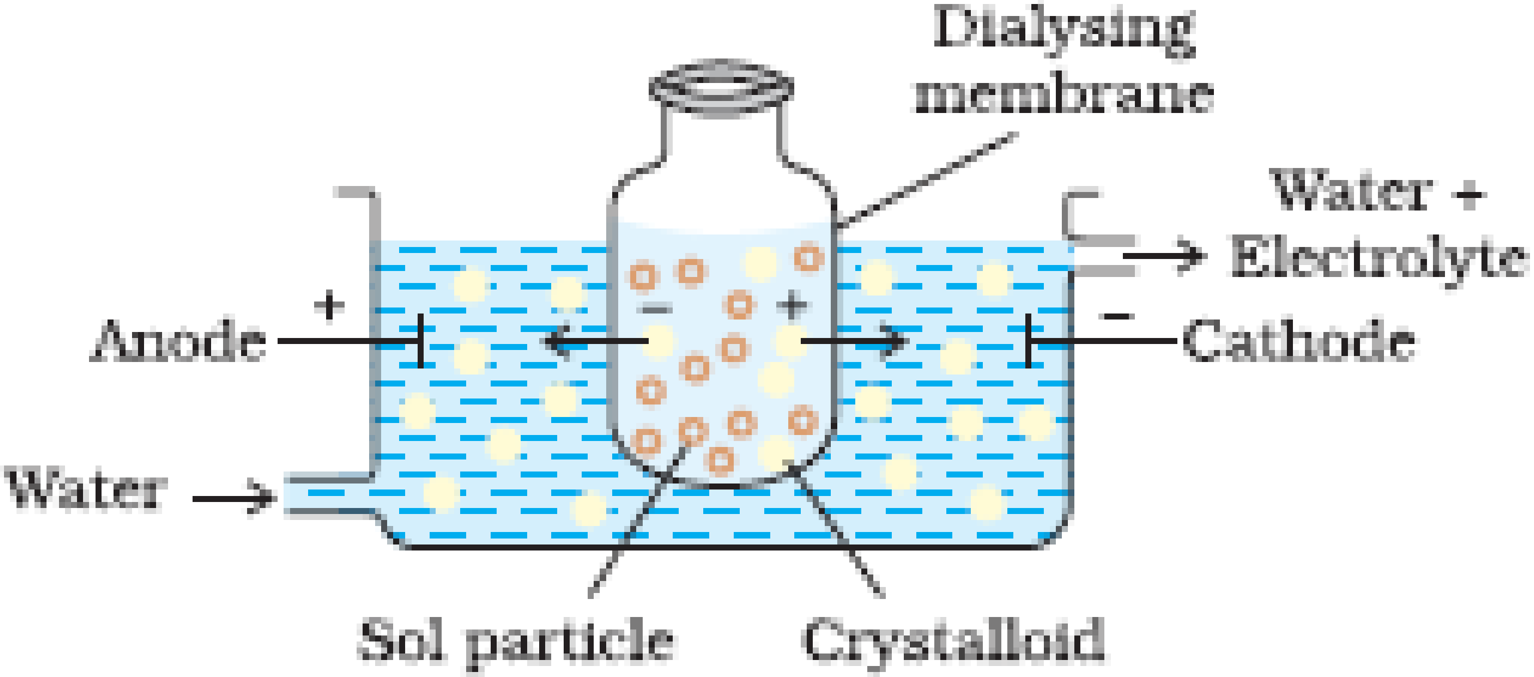
- **The process used for reducing the amount of impurities to a requisite minimum is known as purification of colloidal solution.**
- **The** purification of colloidal solution is carried out by the following mehods:
- (i) *Dialysis:*
- (ii) *Electro-dialysis:*
- (iii) *Ultrafiltration:*

(i) *Dialysis*:

- ***It is a process of removing a dissolved* substance from a colloidal solution by means of diffusion through a suitable membrane.**



(ii) *Electro-dialysis:*



(iii) *Ultrafiltration:*

- Ultrafiltration is the process of separating thecolloidal particles from the solvent and soluble solutes present in the colloidal solution by specially 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 **colloidion solution to stop the flow of** colloidal particles.

(iii) *Ultrafiltration:*

- The usual colloidion is a 4% solution of nitrocellulose in a mixture of alcohol and ether.
- An ultra-filter paper may be prepared by soaking the filter paper in a colloidion solution, hardening by formaldehyde and then finally drying it.
- Thus, by using ultra-filter 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 applied. The colloidal particles left on the ultra-filter paper are then stirred with fresh dispersion medium (solvent) to get a pure colloidal solution.

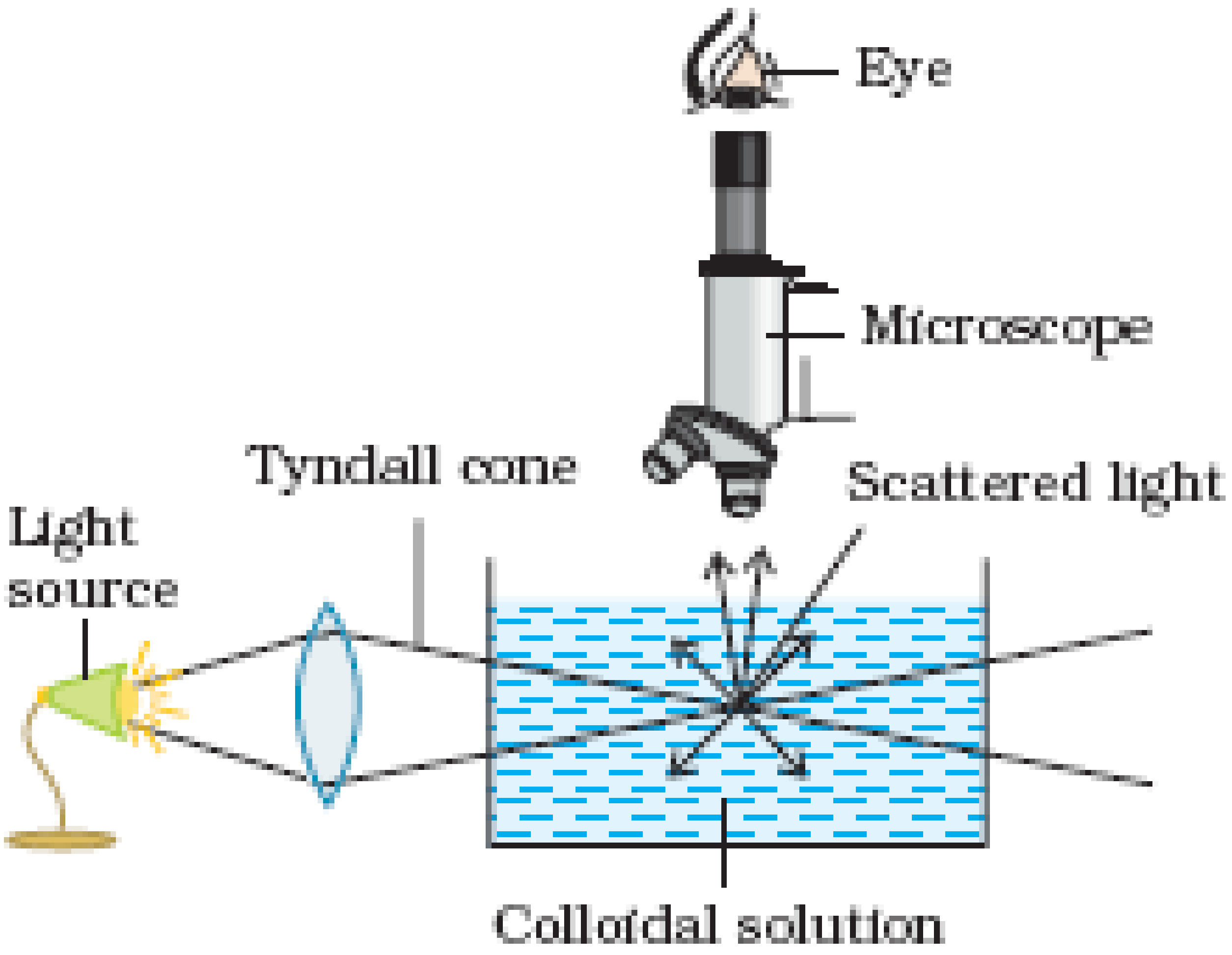
Properties of Colloidal Solutions

- (i) *Colligative properties:*
- (ii) *Tyndall effect:*
- (iii) *Colour:*
- (iv) *Brownian movement:*
- (v) *Charge on colloidal particles:*
- (vi) *Electrophoresis:*
- (vii) *Coagulation or precipitation:*

(i) *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.

(ii) *Tyndall effect*



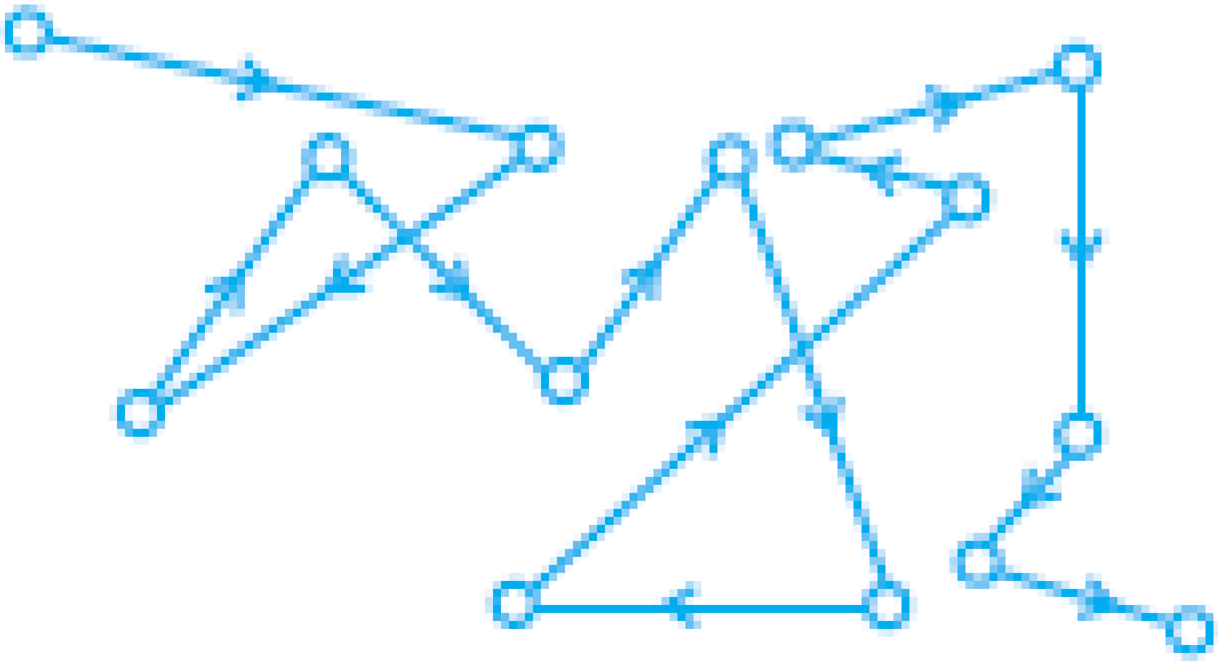
(ii) *Tyndall effect*

- The Tyndall effect is due to the fact that colloidal particles scatter light in all directions in space.
- This scattering of light illuminates the path of beam in the colloidal dispersion.
- Tyndall effect is observed only when the following two conditions are satisfied.
- (i) The diameter of the dispersed particles is not much smaller than the wavelength of the light used; and
- (ii) The refractive indices of the dispersed phase and the dispersion medium differ greatly in magnitude.

(iii) *Colour:*

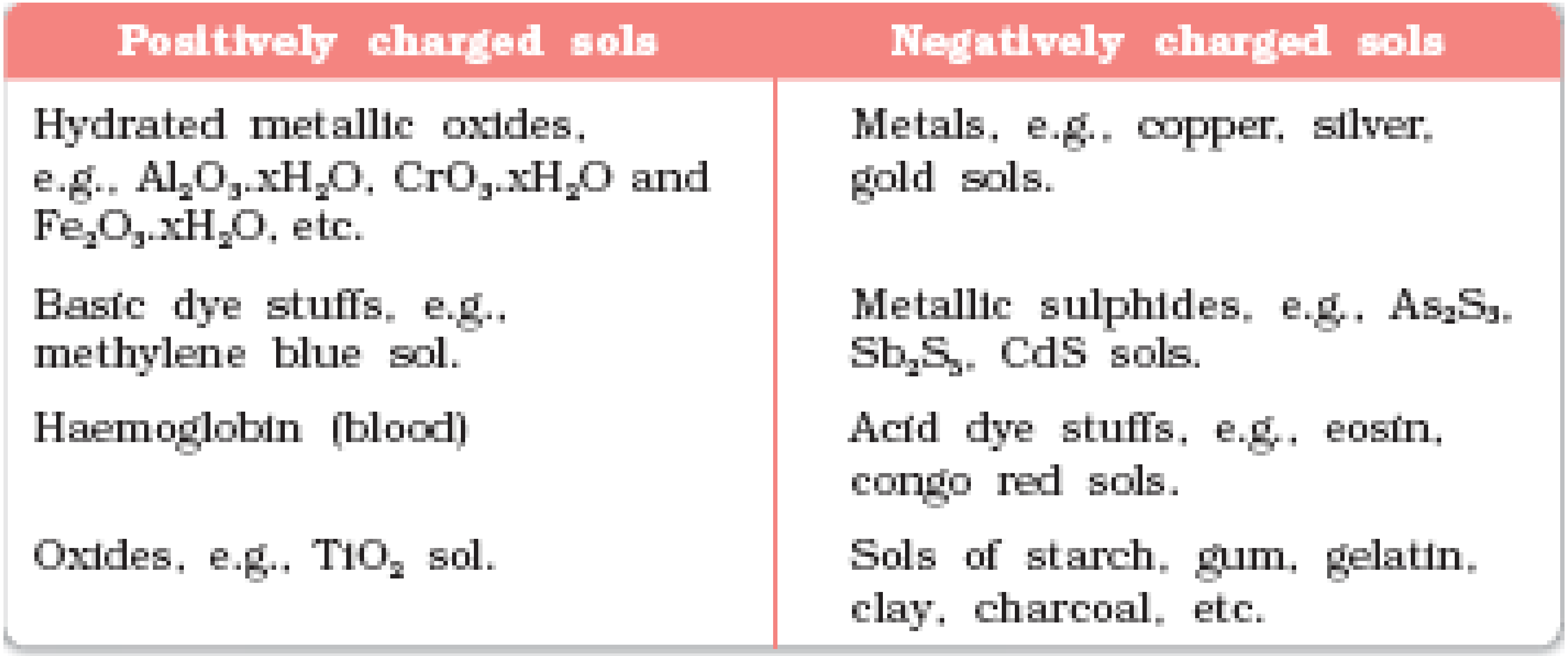
- The colour of colloidal solution depends on the wavelength of light scattered by the dispersed particles.
- The wavelength of light further depends on the size and nature of the particles.
- The colour of colloidal solution also changes with the manner in which the observer receives the light.
- Finest gold sol is red in colour; as the size of particles increases, it appears purple, then blue and finally golden.

(iv) *Brownian movement:*



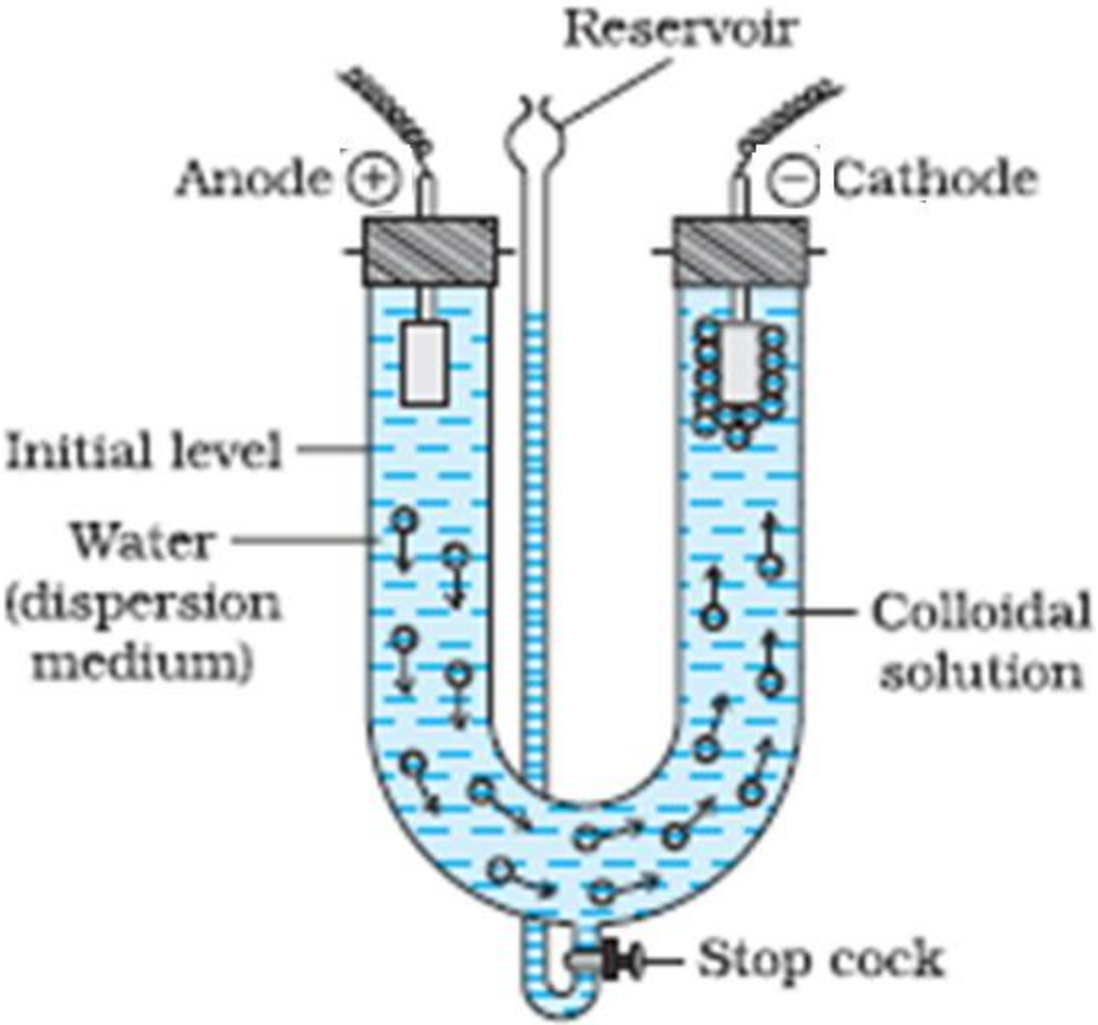
(v) *Charge on colloidal particles*:

- Colloidal particles always carry an electric charge.



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 sulphides, 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.

(vi) *Electrophoresis:*



(vii) *Coagulation or precipitation:*

- **The process of settling of colloidal particles is called coagulation or precipitation of the sol.**
- (i) *By electrophoresis:*
- (ii) *By mixing two oppositely charged sols:*
- (iii) *By boiling:*
- (iv) *By persistent dialysis:*
- (v) *By addition of electrolytes:*

Coagulation of lyophilic sols

- There are two factors which are responsible for the stability of lyophilic sols.
- These factors are the **charge** and **solvation** of the colloidal particles.
- When these two factors are removed, a lyophilic sol can be coagulated.
- This is done by
- (i) adding an electrolyte and
- (ii) adding a suitable solvent.

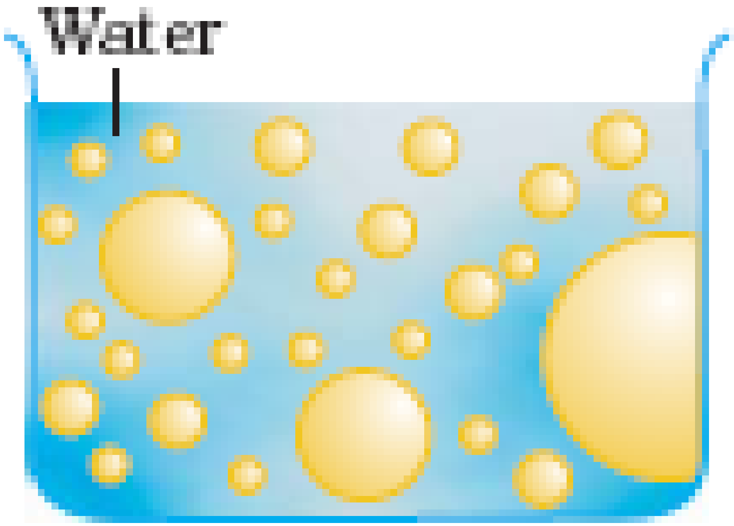
Protection of colloids

- Lyophilic colloids have a unique property of protecting lyophobic colloids.
- When a lyophilic sol is added to the lyophobic sol, the lyophilic particles form a layer around lyophobic particles and thus protect the latter from electrolytes.
- Lyophilic colloids used for this purpose are called protective colloids.

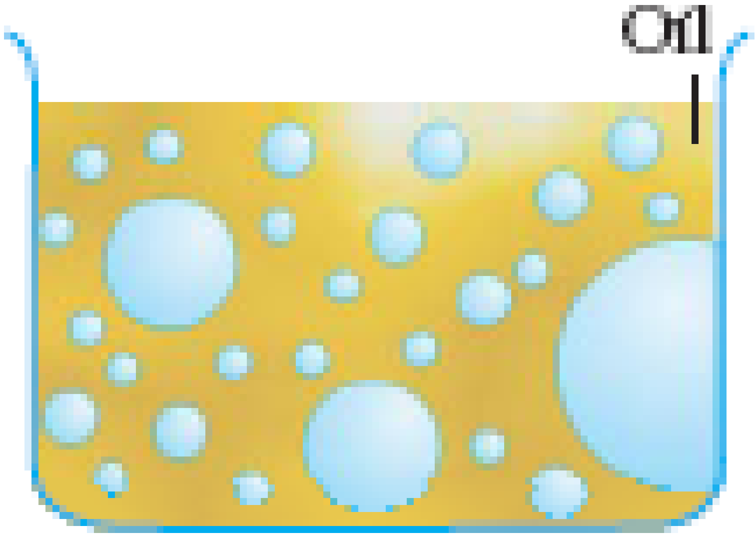
Emulsions

- These are liquid-liquid colloidal systems, i.e., the dispersion of finely divided droplets in another liquid.
- If a mixture of two immiscible or partially miscible liquids is shaken, a coarse dispersion of one liquid in the other is obtained which is called emulsion. Generally, one of the two liquids is water.
- There are two types of emulsions.
- (i) Oil dispersed in water (O/W type) and
- (ii) Water dispersed in oil (W/O type).

Types of emulsions



Oil in water



Water in oil

Colloids Around Us

- Most of the substances, we come across in our daily life, are colloids.
- The meals we eat, the clothes we wear, the wooden furniture we use, the houses we live in, the newspapers we read, are largely composed of colloids.
- Following are the interesting and noteworthy examples of colloids:
- (i) ***Blue colour*** *of the sky:*
- (ii) ***Fog, mist and rain:***

Colloids Around Us

- **(iii)** ***Food articles****:* Milk, butter, halwa, ice creams, fruit juices, etc., are all colloids in one form or the other.
- **(iv)** ***Blood****:* It is a colloidal solution of an albuminoid substance. The styptic action of alum and ferric chloride solution is due to coagulation of blood forming a clot which stops further bleeding.
- **(v)** ***Soils****:* Fertile soils are colloidal in nature in which humus acts as a protective colloid.
- **(vi)** ***Formation of delta****:* River water is a colloidal solution of clay. Sea water contains a number of electrolytes. When river water meets the sea water, the electrolytes present in sea water coagulate the colloidal solution of clay resulting in its deposition with the formation of delta.

Applications of colloids

(i) *Electrical precipitation of smoke:*

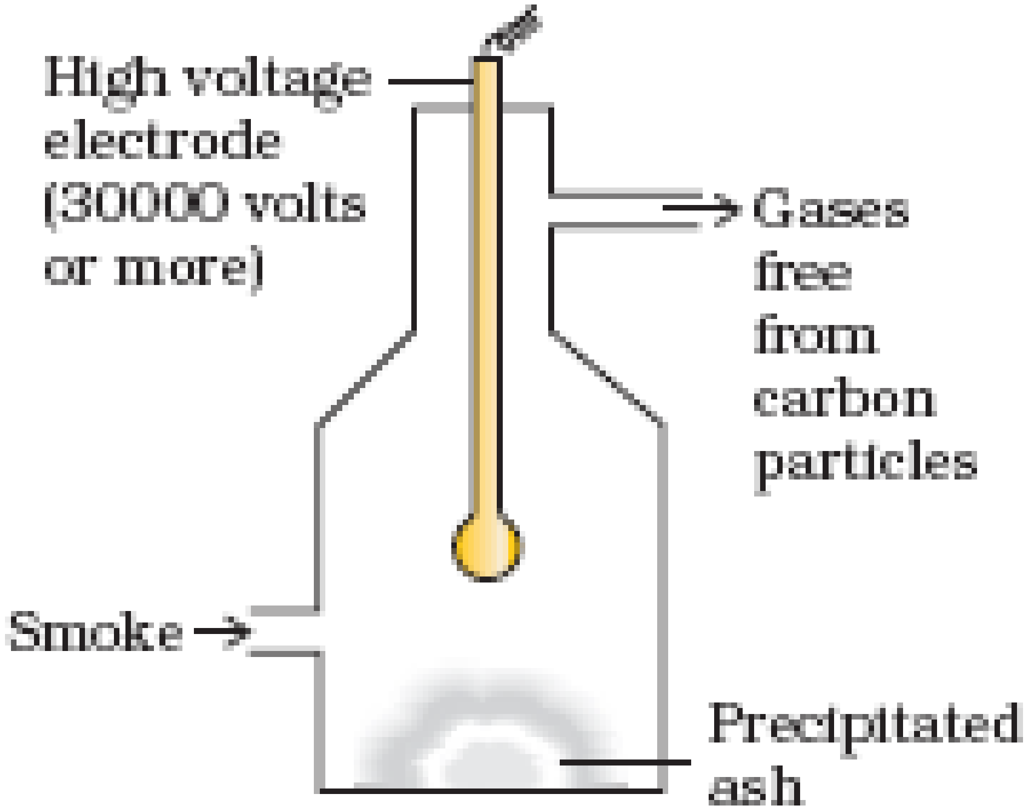


Fig. 5.15: Cottrell smoke precipitator

Applications of colloids

(ii) *Purification of drinking water:*

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

Applications of colloids

(iii) *Medicines:*

- Most of the medicines are colloidal in nature.
- For example, argyrol is a silver sol used as an eye lotion.
- Colloidal antimony is used in curing kalaazar.
- Colloidal gold is used for intramuscular injection.
- Milk of magnesia, an emulsion, is used for stomach disorders.
- Colloidal medicines are more effective because they have large surface area and are therefore easily assimilated.

Applications of colloids

- (iv) *Tanning:*
- (v) *Cleansing action of soaps and detergents:*
- (vi) *Photographic plates and films:*
- (vii) *Rubber industry:*
- (viii) *Industrial products:*

Paints, inks, synthetic plastics, rubber, graphite lubricants, cement, etc., are all colloidal solutions.

Thank You!