

Chapter 5: Surface Chemistry

1. Adsorption: -

(i) The accumulation of molecules species at the surface rather in the bulk of a solid or liquid is termed as adsorption. Examples, water vapours on silica gel.

(ii) It is a surface phenomenon.

(iii) The concentration of adsorbate increases only at the surface of adsorbent.

- **Adsorbate:** The substance which is being adsorbed on the surface of another substance is called adsorbate.
- **Adsorbent:** The surface on which adsorption occurs is called adsorbent.
- **Desorption:** It is the process of removing an adsorbed substance from a surface on which it is adsorbed is known as Desorption. The importance of desorption is provide the surface again for more reaction.

2. Absorption:

(i) It is the phenomenon in which a substance is uniformly distributed throughout the bulk of the solid. Example, water vapour absorbed by anhydrous CaCl_2 .

(ii) It is a bulk phenomenon.

(iii) The concentration is uniformed throughout the bulk of solid.

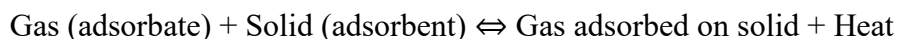
3. Sorption:-When adsorption and absorption both takes place simultaneously.

4. Type of adsorption: There are two types of adsorption: (i) Physical adsorption (physisorption) (ii) Chemical adsorption (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 ($20-40 \text{ kJ mol}^{-1}$) in this case.	5. Enthalpy of adsorption is high ($80-240 \text{ kJ mol}^{-1}$) in this case.
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.

5. Factors Affecting Adsorption:

- (i) **Nature of adsorbent:** Same gas may be adsorbed to different extents on different adsorbent.
- (ii) **Surface area of the adsorbent:** Greater the surface area, greater is the extent of adsorption.
- (iii) **Nature of the gas being adsorbed:** Greater is the critical temperature of a gas, greater is the van der Waals' forces of attraction and thus, greater is the adsorption.
- (iv) **Temperature:** Adsorption is an exothermic process involving the equilibrium:



Applying Le-Chatelier principle, increase of temperature decreases the adsorption and vice versa.

(v) **Pressure:** Adsorption increases with pressure at constant temperature. The effect is large if temperature is kept constant at low value.

(vi) **Activation of the solid adsorbent:** Activation of adsorbent means increasing the adsorbing power of the solid adsorbent. This can be achieved by following ways-

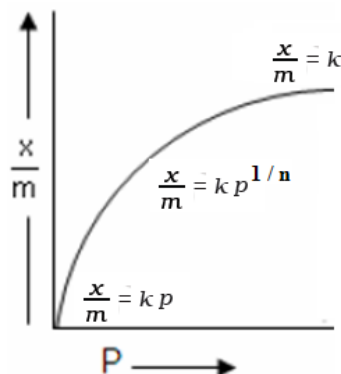
- Increasing the surface area of adsorbent by breaking it into small pieces.
- By removing the gases already adsorbed by passing superheated steam.
- By making the surface of adsorbent rough.

6. Adsorption isotherm: The variation in the amount of gas adsorbed by the adsorbent with pressure at constant temperature can be expressed thus obtained curve is known as adsorption isotherm.

Freundlich adsorption isotherm (Effect of pressure on adsorption): According to Freundlich, the relationship between magnitude of adsorption (x/m) and pressure of the gas at constant temperature can be expressed as

$$\frac{x}{m} = k \cdot p^{1/n} \quad (n > 1) \text{ ----- (1)}$$

Where x is the mass of the gas adsorbed on mass m of the adsorbent at pressure p . k and n are constants which depend on the nature of the adsorbent and the gas at a particular temperature. x/m first increases with increase in pressure at low pressure but becomes independent of pressure at high pressure.



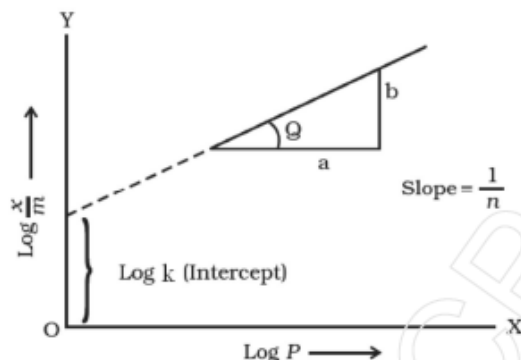
Freundlich isotherm explains the behaviour of adsorption in an approximate manner. The factor $1/n$ can have values b/w 0 and 1, hence, equation -1

- At high pressure range, $1/n = 0$ then
 $x/m = k$, which shows the adsorption is independent of pressure.
- At low pressure range, $1/n = 1$ then
 $x/m = k p$ or $x/m \propto p$, the adsorption varies directly with pressure.

Taking logarithm on both sides of equation 1, then we get,

$$\log \frac{x}{m} = \log k + \frac{1}{n} \log p \quad \text{----- (2)}$$

If we plot a graph between $\log x/m$ and $\log P$, we get a straight line. The slope of the line is $1/n$ and intercept will be equal to $\log k$.



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: Freundlich given the relationship b/w magnitude of adsorption (x/m) and equilibrium concentration 'C' of solution at constant temperature can be expressed as

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

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

If we plot a graph between $\log x/m$ and $\log C$, we get a straight line, which shows the validity of Freundlich isotherm.

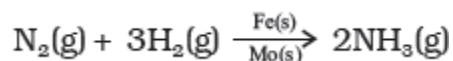
7. Application of adsorption:

- For production of high vacuum.
- Gas masks containing activated charcoal which is used for breathing in coalmines. They adsorb poisonous gases.
- Silica and aluminum gels are used as adsorbents for controlling humidity.
- Removal of coloring matter from solutions using animal charcoal.
- It is used in heterogeneous catalysis.
- In separation of inert gas.
- As adsorption indicators.
- In chromatographic analysis which is based on adsorption.
- Qualitative analysis, e.g., lake test for Al^{3+} .

Catalyst

1. Catalyst: Substances which accelerate the rate of chemical reaction and themselves remain chemically and quantitatively unchanged after the reaction are known as catalyst and the phenomenon is known as catalysis.

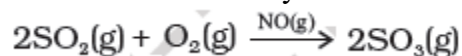
- **Promoters:** Promoters are substances that enhance the activity of catalyst. For example, in Haber's process for manufacture of ammonia, molybdenum acts as a promoter for iron which is used as a catalyst.



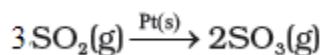
- **Catalytic poisons (inhibitors):** These are the substances which decrease the activity of catalyst. Examples, Arsenic act as catalytic poisons in the manufacture of sulphuric acid by contact process.
CO acts as catalytic poison during preparation of ammonia by Haber's process so must be removed it during process.

2. Types of Catalyst:

(i) **Homogenous catalyst:** When reactants and catalyst are in same phase.

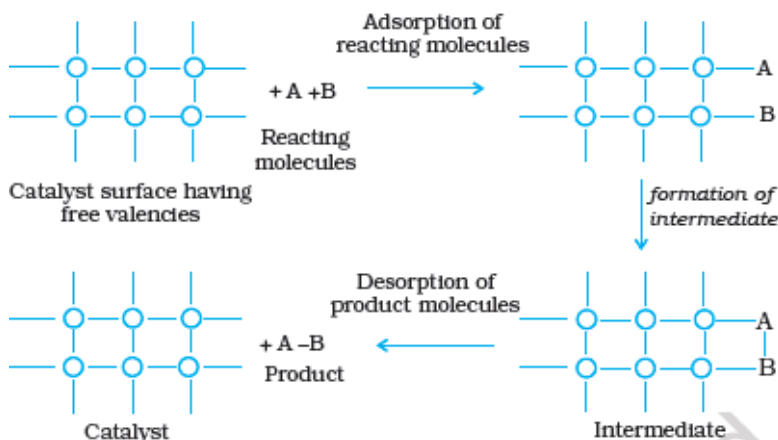


(ii) **Heterogeneous catalyst:** The catalytic process in which the reactants and catalyst are in different phase.



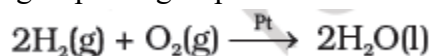
3. Adsorption theory of Heterogeneous catalysis: It explains the mechanism of heterogeneous catalyst. The mechanism involves 5 steps:

- (i) Diffusion of reactants to the surface of catalyst.
- (ii) Adsorption of reactant molecules on the surface of catalyst.
- (iii) Chemical reaction on the catalyst surface through formation of an intermediate.
- (iv) Desorption of reaction product from the catalyst surface.
- (v) Diffusion of reaction product away from the catalyst surface.

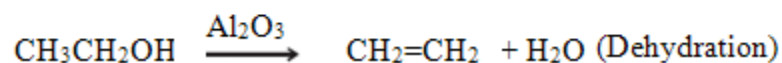
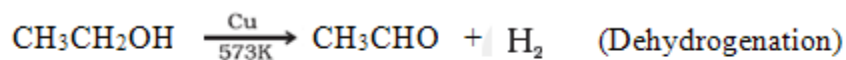


4. Important features of solid catalyst:

(i) **Activity of catalyst:** The ability of a catalyst to increase the rate of a chemical reaction is called activity of a catalyst. For example, a mixture of hydrogen and oxygen does not react at all under normal conditions but in the presence of platinum they react with explosive violence. Catalytic activity increases from group 5 to group 11 elements of the periodic table.



(ii) **Selectivity of catalyst:** It is the ability of catalyst to direct a reaction to yield a particular product (excluding others). For example, ethanol react to form different products in presence of different catalysts as follows:



5. Shape-selective catalysis: The catalysis which depends upon the pore structure of the catalyst and molecular size of reactant and product molecules is called shape- selective catalysis. Examples, Zeolites are shape-selective catalysts due to their honey- comb structure.

Note: Zeolites (microporous aluminosilicate) are 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.

6. Catalysis in Industry:

- **Haber process for manufacturing of Ammonia:** Catalyst is FeO with small amount of K_2O and Al_2O_3 . Molybdenum as promoters.
- **Contact process for manufacturing of Sulphuric acid:** Platinised asbestos or V_2O_5 .
- **Ostwald's process for manufacturing of Nitric acid:** Platinised asbestos.

Enzymes

1. Enzymes: Enzymes are essential biological catalysts which are required to catalyse biological reactions. Almost all the enzymes are globular proteins. Following are the examples of enzyme-catalysed and their reactions:

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

Some other examples of enzymatic catalysis reactions:

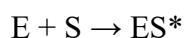
- In stomach, the pepsin enzyme converts proteins into peptides while in intestine, the pancreatic trypsin converts proteins into amino acids.
- Conversion of milk into curd by lacto bacilli enzyme present in curd.
- Ptyalin enzyme present in human saliva converts starch into glucose.

2. Characteristics of enzyme catalysis:

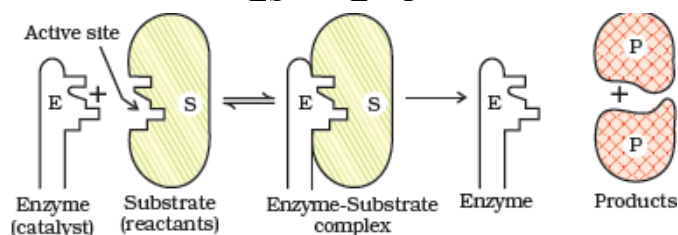
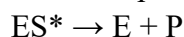
- a) They are highly efficient. One molecule of an enzyme can transform 10⁶ molecules of reactants per minute.
- b) They are highly specific in nature means one enzyme catalyst cannot catalyse more than one reaction, e.g., urease catalysis hydrolysis of urea only.
- c) They are highly active at definite temperature (25°C – 37° C) called the optimum temperature.
- d) They are highly active at a specific pH called optimum pH.
- e) Enzymatic activity can be increased in presence of coenzymes which can be called as promoters.
- f) Activators are generally metal ions Na⁺, Co²⁺ and Cu²⁺ etc. They weakly bind to enzyme and increase its activity.
- g) Enzymes can also be inhibited or poisoned by the presence of certain substances.

3. Mechanism of Enzyme action: The enzyme-catalysed reactions may be considered to proceed in two steps:

- a) Binding of enzyme to substrate to form an activated complex.



- b) Decomposition of the activated complex to form product.



Colloids and Colloidal Solutions

1. Colloids: A colloid is a heterogeneous system in which one substance is dispersed (dispersed phase) in another substance called dispersion medium and size of dispersed phase is from 1nm-1000 nm.

$$\text{Dispersed phase} + \text{Dispersion medium} = \text{Dispersed system (Colloidal solution)}$$

- **Dispersed phase:** The phase of colloid particle is called dispersed phase. This is like a solute in the solution.
- **Dispersion medium:** The medium in which dispersed particles are dispersed is called dispersion medium. This is like a solvent in true solutions. If water being the medium, colloids are called hydrosols.
- **Crystalloids:** The substances whose aqueous solutions can pass the semipermeable membrane are called crystalloids.

2. Distinction between True solution, Colloids and Suspension:

True solution	Colloids	Suspension
It is homogeneous	It appears to be homogeneous but is actually heterogeneous	It is heterogeneous
The diameter of the particles is less than 1 nm	The diameter of the particles is 1 nm to 1000 nm	The diameter of the particles are larger than 1000 nm
It passes through filter paper	It passes through ordinary filter paper but not through ultra-filters	It does not pass through filter paper
Its particles cannot be seen under a microscope	Its particles can be seen by a powerful microscope due to scattering of light	Its particles can be seen even with naked eye

3. Classification of Colloids:

(i) Classification based on Physical state of dispersed phase & dispersion medium:

Dispersed phase	Dispersion medium	Type of Colloid	Example
Gas	Gas	No colloidal solution	~
Gas	Solid	Solid sol	Pumice stone, foam rubber
Gas	Liquid	Foam	Whipped cream, soap lather
Liquid	Solid	Gel	Cheese, butter, jellies
Liquid	Liquid	Emulsion	Milk, hair, cream
Liquid	Gas	Aerosol	Fog, mist, cloud
Solid	Solid	Solid sol	Some coloured glasses and gem stones
Solid	Liquid	Sol	Paint, cell fluids
Solid	Gas	Aerosol	Smoke, dust

(ii) Classification based on nature of interaction b/w dispersed phase & dispersion medium:

Sr.No.	Lyophobic Colloids	Lyophilic Colloids
1	These colloids are liquid hating.	These colloids are liquid loving.
2	In these colloids the particles of dispersed phase have no affinity for the dispersion medium.	In these colloids, the particles of dispersed phase have great affinity for the dispersion medium.
3	They are not stable.	They are stable.
4	They can be prepared by mixing substances directly.	They cannot be prepared by mixing substances directly. They are prepared only by special methods.
5	They need stabilizing agents for their preservation.	They do not need stabilizing agents for their preservation.
6	They are irreversible solution.	They are reversible solution.
7	They are also called Extrinsic colloids.	They are also called Intrinsic colloids.
8	Examples- Sols of gold, silver, Fe(OH) ₃ etc.	Examples- gums, gelatin, starch, albumin etc.

(iii) Classification of Colloids based on type of particles of the dispersed phase:

(a) Multimolecular colloid:

On dissolution, a large number of atoms or smaller molecules of a substance aggregate together to form species having size in colloidal range (less than 1 nm). The species thus formed are called Multimolecular colloids. Examples are sulphur sol, gold sol, platinum sol etc. Multimolecular colloids are generally lyophobic in nature.

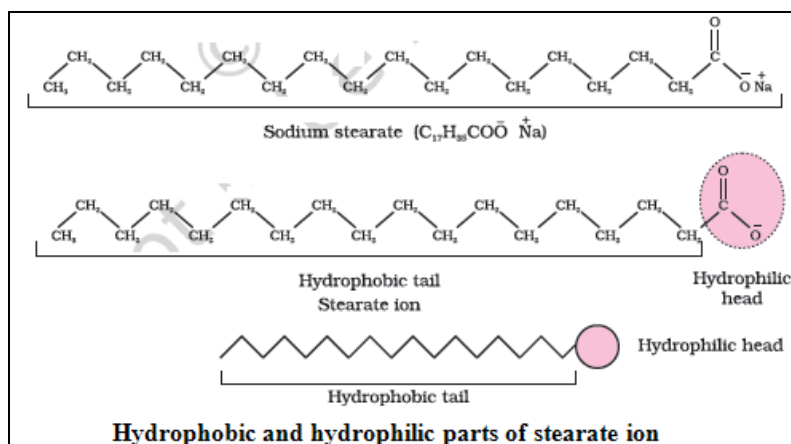
(b) Macromolecular colloids: These are the colloids in which the dispersed particles are themselves large molecules (usually polymers). Since these molecules have dimensions comparable to those of colloids particles, their dispersions are called macromolecular colloids. Examples, proteins, starch and cellulose form macromolecular colloids.

(c) Associated colloids (Micelles): Some substances in low concentration behave as normal strong electrolyte but at higher concentration behave as colloidal due to the formation of aggregates particles such aggregated particles are called micelles and also known as associated colloids. Examples are soap and detergents.

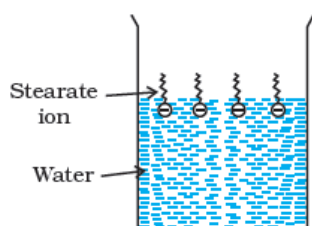
- **Kraft temperature (T_k):** The temperature above which the formation of micelles takes place is called Kraft temperature.
- **Critical micelle concentration (CMC):** Concentration above which the formation of micelles takes place is known as CMC.

4. Mechanism of Micelles formation: For understand the mechanism of micelles; let us take the example of soap solutions.

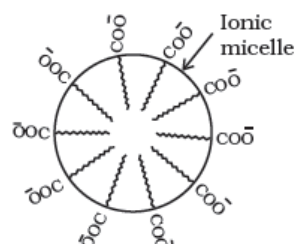
- **Soap** is sodium or potassium salt of a higher fatty acid and may be represented as RCOO^-Na^+ (e.g., sodium stearate $\text{CH}_3(\text{CH}_2)_{16}\text{COO}^-\text{Na}^+$).
- When it dissolved in water, it dissociates into RCOO^- and Na^+ ions.
- The RCOO^- ions, however, consist of two parts, a long hydrocarbon chain R (also called non-polar 'tail') which is hydrophobic and a polar group COO^- (also called polar-ionic 'head') which is hydrophilic (water loving).



- 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.
- 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'.
- Similarly, in case of detergents, e.g., sodium laurylsulphate, CH₃(CH₂)₁₁SO₄⁻Na⁺, the polar group is SO₄⁻ 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 low concentrations of soap



(b) Arrangement of stearate ions inside the bulk of water (ionic micelle) at critical micelle

5. Cleansing action of soaps:

- It 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 (see fig).
- 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.
- Thus soap helps in emulsification and washing away of oils and fats. The negatively charged sheath around the globules prevents them from coming together and forming aggregates.



(a) Grease on cloth



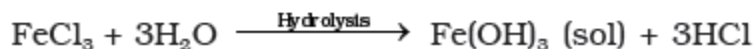
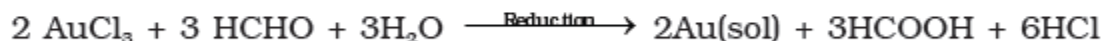
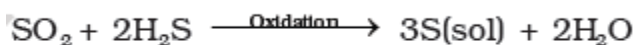
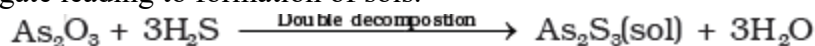
(b) Stearate ions arranging around the grease droplet



(c) Grease droplet surrounded by stearate ions (micelle formed)

6. Methods of preparation of colloids:

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



(ii) **Electrical disintegration or Bredig's Arc method:** In this method, electric arc is struck between electrodes of the metal immersed in the dispersion medium. The intense heat produced vaporizes the metal which then condenses to form particles of colloidal size. Colloidal sols of metals such as gold, silver, platinum, etc., can be prepared by this method.

(iii) **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.

7. Purification of colloids:

(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:** 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 an electrolyte.

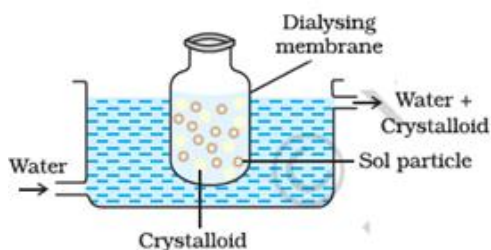


Figure: Dialysis

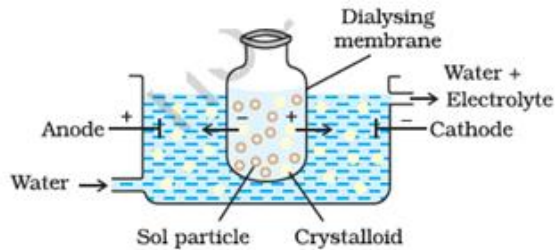


Figure: Electro dialysis

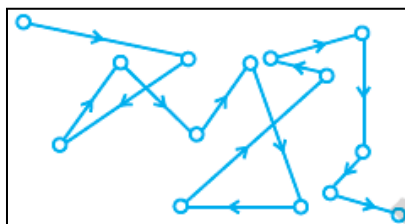
(iii) **Ultrafiltration:** Ultra filtration is the process of separating the colloidal particles from the solvent and soluble solutes present in the colloidal solution by specially prepared filters, which are permeable to all substances except the colloidal particles.

(iv) **Ultracentrifugation:** In this process, the colloidal solution is taken in a tube which is placed in ultracentrifuge. On rotating the tube at very high speed, the colloidal particles settle down at the bottom of the tube and the impurities remain in solution. The settled particles are mixed with dispersion medium to regenerate the sol.

8. Properties of colloids:

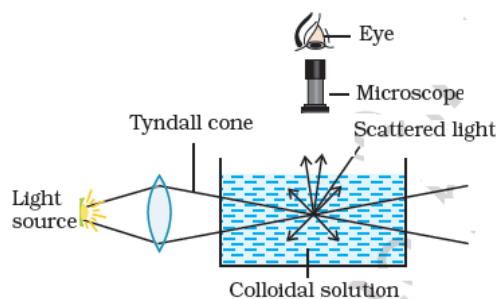
(i) Brownian movement:

- Colloidal particles move in zig – zag path. This type of motion is due to the colliding molecules of dispersion medium constantly with colloidal particles.
- This motion is depends on the size of the particles and viscosity of the solution. Smaller the size and lesser the viscosity, faster is the motion.
- The Brownian movement has a stirring effect which does not permit the particles to settle and thus, is responsible for the stability of sols.



(ii) Tyndall effect:

- The scattering of a beam of light by colloidal particles is called Tyndall effect. The bright cone of light is called the Tyndall cone.
- Tyndall effect is observed only when the following two conditions are satisfied-
 - (a) The diameter of the dispersed particles is not much smaller than the wavelength of the light used; and
 - (b) The refractive indices of the dispersed phase and the dispersion medium differ greatly in magnitude.
- Tyndall effect is used to distinguish between a colloidal and true solution.



(iii) Colligative properties: 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 the same concentrations.

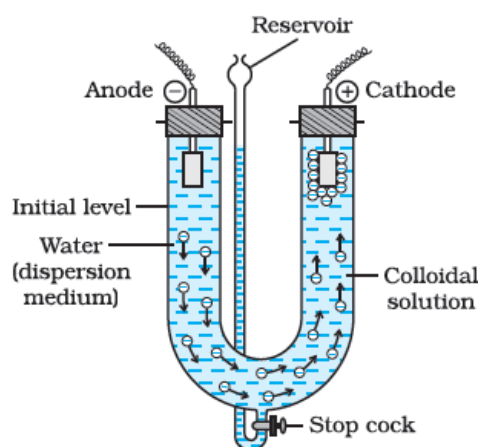
(iv) Charge on colloidal particles: Colloidal particles always carry an electric charge. The nature of this charge is the same on all the particles in a given colloidal solution and may be either positive or negative.

Positively charged colloids	Negatively charged colloids
Hydrated metallic oxides such as $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, $\text{Cr}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$	Metallic sulphides like As_2S_3 , Sb_2S_3 sols
Basic dye stuff like malachite green, methylene blue sols	Acid dye stuff like eosin, methyl orange, Congo red sols
Haemoglobin (blood)	Starch sol, gum, gelatin, clay, charcoal, egg albumin, etc.

(v) **Helmholtz electrical double layer:** When the colloidal particles acquire negative or positive charge by selective adsorption of one of the ions, it attracts counter ions from the medium forming a second layer. The combination of these two layers of opposite charges around colloidal particles is called Helmholtz electrical double layer.

(vi) **Electrokinetic potential or zeta potential:** The potential difference between the fixed layer and the diffused layer of opposite charges is called electrokinetic potential or zeta potential.

(vii) **Electrophoresis:** The movement of colloidal particles towards oppositely charged electrode under an applied electric field is called electrophoresis. Positively charged particles move towards the cathode while negatively charged particles move towards the anode. This can be demonstrated by the following experimental setup



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

(ix) **Coagulation or precipitation:** The process of settling of colloidal particles as precipitate is called coagulation.

Hardy – Schulze rules for coagulation:

a) Oppositely charged ions are effective for coagulation.

- b) The coagulating power of electrolyte increases with increase in charge on the ions used for coagulation, e.g. for coagulation of a negative sol, the coagulating power is in the order: $\text{Al}^{3+} > \text{Ba}^{2+} > \text{Na}^+$.

Similarly, in the coagulation of a positive sol, the coagulating power is in the order: $[\text{Fe}(\text{CN})_6]^{4-} > \text{PO}_4^{3-} > \text{SO}_4^{2-} > \text{Cl}^-$.

Coagulation of the lyophobic sols: It can be carried out in the following ways:

- By electrophoresis.
- By mixing two oppositely charged sols.
- By boiling.
- By persistent dialysis.
- By addition of electrolytes.

Coagulation of lyophilic sols: It is done by:

- By adding an electrolyte
- By adding a suitable solvent. When solvents such as alcohol and acetone are added to hydrophilic sols, the dehydration of dispersed phase occurs. Under this condition, a small quantity of electrolyte can bring about coagulation.

Gold Number: It is defined as the minimum amount of protective colloid in milligrams which prevents from coagulation of 10ml gold sol by the addition of 1 ml of 10%NaCl solution. The smaller the gold number, the higher is the protecting power of lyophilic colloids.

9. Emulsion: Emulsions are colloidal systems in which both the dispersed and phase and dispersion medium are liquids. There are two types of emulsions-

(i) Types of emulsions:

(a) Water dispersed in oil: When water is the dispersed phase and oil is the dispersion medium. E.g. butter.

(b) Oil dispersed in water: When oil is the dispersed phase and water is the dispersion medium. E.g. milk.

(ii) Emulsification: The process of stabilizing an emulsion by means of an emulsifier.

(iii) Emulsifying agent: The substances which are added to stabilize the emulsions are called emulsifying agents or emulsifiers. E.g. soaps, gum

(iv) Demulsification: The process of breaking an emulsion into its constituent liquids is called demulsification by freezing, boiling, centrifugation or some chemical methods.

10. Colloids around us:

(i) Blue colour of the sky: Dust particles along with water suspended in air scatter blue light which reaches our eyes and the sky looks blue to us.

(ii) Clouds, Fog and mist: Clouds and fog are aerosols having small droplets of water suspended in air.

(iii) Food articles: Milk, butter, halwa, ice creams, fruit juices, etc., are all colloidal in nature.

(iv) Blood: It is a colloidal solution of an albuminoid substance. By applying alum and ferric chloride solution, forming a clot with blood and it stoppage the bleeding.

(v) 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.

11. Applications of colloids:

(i) Electrical precipitation of smoke

(ii) Cleansing action of soaps and detergents

(iii) Purification of drinking water: The water which contains suspended impurities. Alum is added to such water to coagulate the suspended impurities and make water fit for drinking purposes.

(iv) 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.

(v) Tanning: Animal hides are colloidal in nature. When a hide, which has positively charged particles, is soaked in tannin, which contains negatively charged colloidal particles, mutual coagulation takes place. This results in the hardening of leather. This process is termed as tanning. Chromium salts are also used in place of tannin.

(vi) Rubber industry: Latex is a colloidal solution of rubber particles which are negatively charged. Rubber is obtained by coagulation of latex.

(vii) Industrial products: Paints, inks, synthetic plastics, rubber, graphite lubricants, cement, etc., are all colloidal solutions.