SURFACE CHEMISTRY

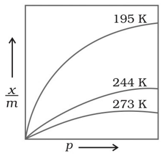
by Apni Kaksha

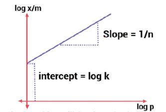
Class XII Board Exams

- Verified by CBSE Science Topper's
- All PYQ's Integrated
- **BEST NOTES** for Class XII Board Exams

Aman Dhattarwal

Flow Chart

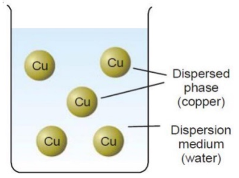


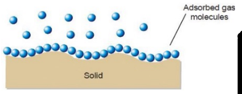


Plotting of freundlich Adsorption isotherm

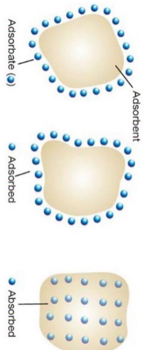
Surface Chemistry

- Freundlich Isotherm
- Colloids
  - Disperse Phase
  - Dispersion Medium

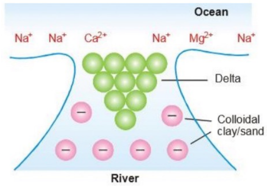


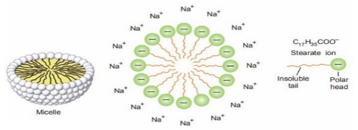


- Adsorption
- Absorption
- Desorption
- Sorption
- Types of adsorption
  - Physisorption
  - Chemisorption

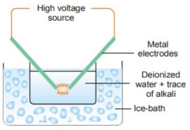


- Classification of Colloids
  - On the basis of physical state
  - On the basis of interaction b/w DP & DM.
    - Lyophobic Sol
    - Lyophilic Sol
  - On the basis of types of particles of DP.
    - Multimolecular Colloids
    - Macromolecular Colloids
    - Associated Colloids
      - Micelles
      - Cleaning of soap

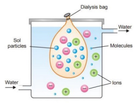


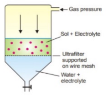


- Preparation
  - Chemical Method
  - Bredig's Arc Method
  - Peptization

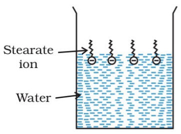


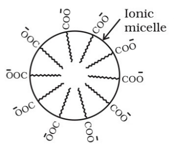
- Purification
  - Dialysis
  - Ultra-Filtration

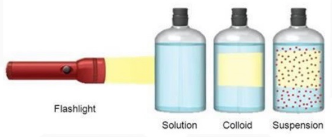


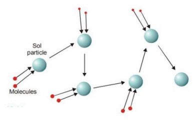


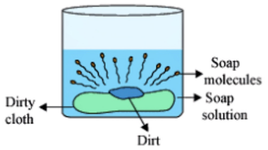
- Properties
  - Tyndall Effect
  - Brownian Motion
  - Electrophoresis
  - Coagulation

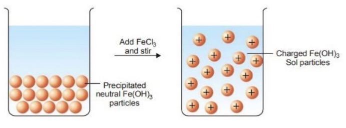


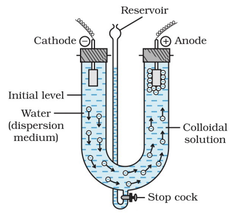












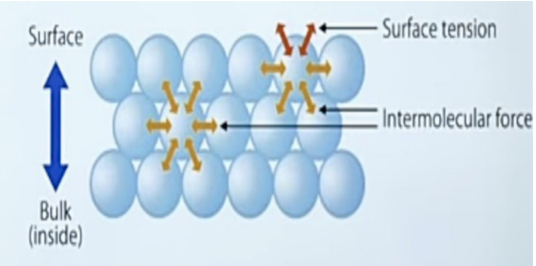
Surface Chemistry

→ Surface chemistry deals with phenomena that occur at the surface or interfaces.

→ The surface or interface is represented by seperating the bulk phases by a hyphen or slash. For example -: (i) Interface between a solid and gas → Solid-gas or $\frac{\text{Solid}}{\text{gas}}$

(ii) Interface between liquid and liquid → Liquid - liquid

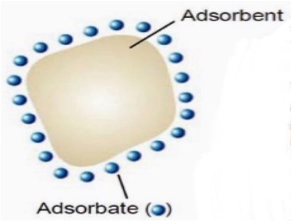
(iii) But there is no interface between two gases, due to complete miscibility.



→ Molecules on surface experiences unbalanced attracted force resulting in a net inward pull. This produces surface tension.

→ Molecules in bulk phases experiences balanced forces from all the directions and are in state of equilibrium.

Adsorption -: The accumulation of molecular species at the surface rather than in bulk of a solid or liquid is termed adsorption. [Delhi 2015C, 2014C | CBSE 2013] (1M)



Adsorbate -: The molecular species or substance which concentrate or accumulates at the surface is termed adsorbate.

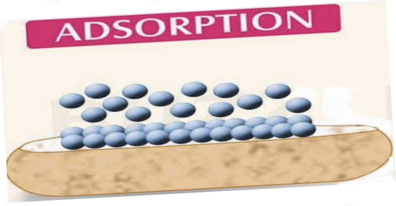
Adsorbent -: The material on the surface of which the adsorption takes place is called adsorbent.

Example → Silica gel, charcoal, colloids.

Adsorption Vs Absorption

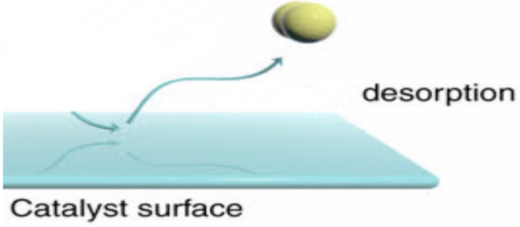
(1M) [Delhi 2016 | CBSE 2010C]

Adsorption	Absorption
(i) The substance is concentrated only at the surface and does not penetrate through surface to the bulk of adsorbent.	(i) The substance is uniformaly distributed throughout the bulk of solid.



Desorption -: The process of removing an adsorbed substance from a surface. [Reverse of adsorption]

[Delhi 2011] (1M)



Sorption :- When adsorption and absorption take place simultaneously. [Delhi 2017C] (1M)

Thermodynamics of adsorption -: [Why is adsorption always exothermic?]

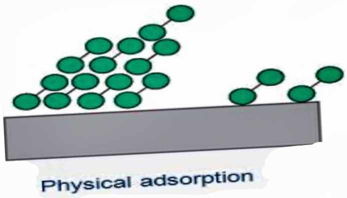
→ During adsorption there is always a decrease in residual forces of surface, there is a decrease in surface energy, which appears as heat. That is why adsorption is an exothermic process. [$\Delta H = \ominus ve$] (1M) [Delhi 2014 | CBSE 2010]

→ After adsorption randomness of the system decreases. So for adsorption $\Delta S = \ominus ve$.

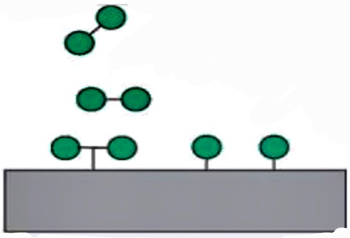
→ For adsorption, thermodynamic requirement is that at constant T and P, ΔG must be negative. [$\Delta G = \ominus ve$] (1M) [Delhi 2010 / 2012C]

$$\underbrace{\Delta G}_{\ominus\text{ ve value}} = \underbrace{\Delta H}_{\text{More }\ominus\text{ value}} - \underbrace{T\Delta S}_{\oplus\text{ ve value}}$$

Types of adsorption -:


Physical adsorption

(i) **Physical Adsorption** :- When the particles of adsorbate are held to the surface of adsorbent by physical forces such as vander waal's forces. Then adsorption is called physical adsorption.


Chemical adsorption

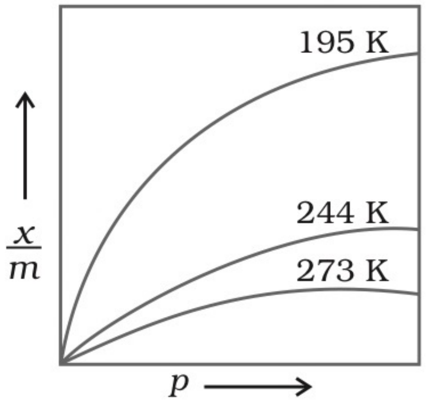
(ii) **Chemical Adsorption** -: When the molecules of adsorbate are held to the surface of the adsorbent by chemical forces, the adsorption is known as chemical adsorption. [Delhi 2011C] (1M)

→ Difference between physisorption and chemisorption

[Delhi 2013] (2M) [CBSE 2015 | 2012] (3M)

Physisorption	Chemisorption
(i) Example → Adsorption of SO_2 on charcoal	(i) Example → Adsorption of H_2 on platinum.
(ii) Lack of specificity -: A given surface of an adsorbent does not show any preference for a particular gas.	(ii) High specificity -: It will only occur if there is some possibility of chemical bonding between adsorbent and adsorbate.
(iii) It arises due to vander waal force.	(iii) It is caused by chemical bond formation
(iv) It is reversible in nature.	(iv) It is irreversible in nature.
(v) As the surface of adsorbent increases physisorption increases.	(v) As the surface area of adsorbent increases chemisorption increases.
(vi) Enthalpy of adsorption is low due to weak force of attraction between adsorbent and adsorbate.	(vi) Enthalpy of adsorption is relatively high due to bond formation [strong attractive force]

Adsorption Isotherms –: The graph between amount of gas adsorbed and pressure at constant temperature is known as adsorption isotherm.



$x \rightarrow$ mass of gas adsorbed.

$m \rightarrow$ mass of adsorbent.

③M [CBSE 2010 | 2010C]

Freundlich adsorption isotherm –:

→ Empirical relationship between quantity of gas adsorbed and pressure at constant temperature.

[CBSE 2014] ①M

$$\boxed{\frac{x}{m} = k\,p^{1/n}} \qquad [0 < n \leq 1]$$

→ k and n are constants which depends on nature of adsorbent and gas.

→ From Graph : (i) As temperature increases extent of adsorption increases.

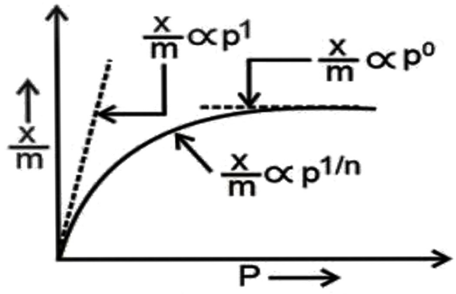
(ii) At low pressure : $\frac{x}{m} \propto p^1$

(iii) At high pressure : $\frac{x}{m} \propto p^0$: curve seem to approach saturation at high pressure.

(iv) At moderate pressure : $\frac{x}{m} \propto p^{1/n}$ where $[0 < n \leq 1]$

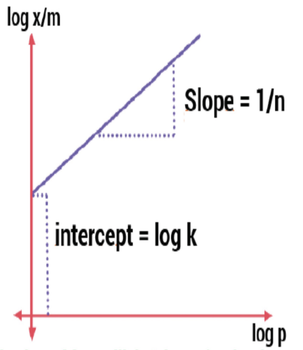
Taking log of $\frac{x}{m} = k\,p^{1/n}$:

$$\underbrace{\log \frac{x}{m}}_{y} = \underbrace{\log k}_{c} + \underbrace{\frac{1}{n}}_{m} \cdot \underbrace{\log p}_{x}$$



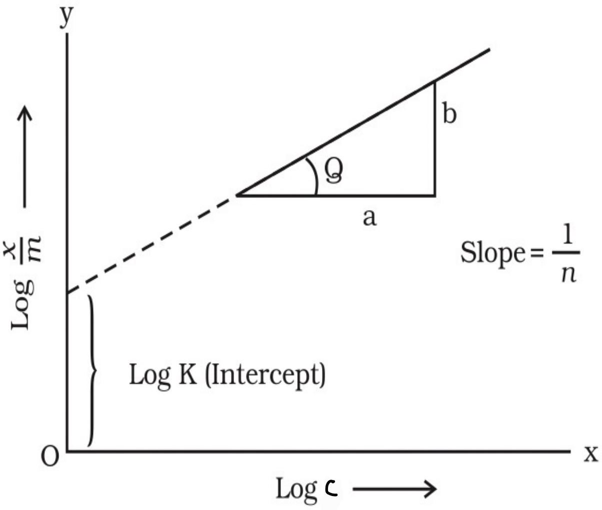
Slope [m] = $\frac{1}{n}$

Intercept [c] = $\log k$



Plotting of freundlich Adsorption isotherm

Adsorption from solution phase :– Solids can adsorb solutes from solutions. Freundlich equation approximately describes the behaviour of adsorption from solution with a difference that instead of pressure, concentration of solution is taken into account.



→ $\frac{x}{m} = k\,c^{1/n}$

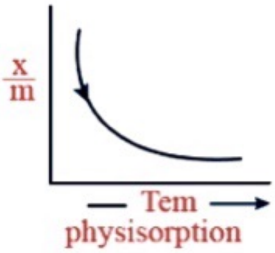
→ $\log \frac{x}{m} = \frac{1}{n} \log c + \log k$

$y = m\,x + c$

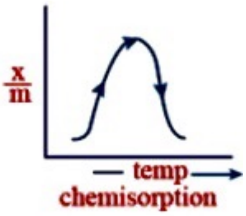
Question :– What is the effect of temperature on physisorption and chemisorption ?

[CBSE 201
Delhi 2014C
(1M)

Answer –: As temperature ↑es
⇓
Physisorption ↓es.



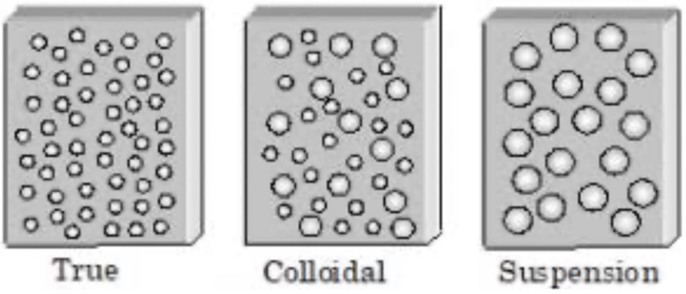
physisorption



chemisorption

→ Chemisorption first increases and then decreases with increase in temperature.
[Delhi 2019] (1M)

Colloids

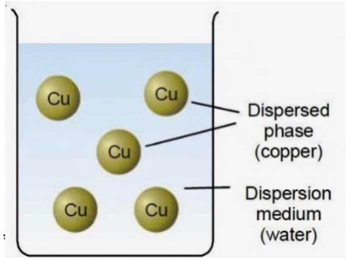


→ The colloidal solutions are intermidiate between true solutions and suspensions.

→ Colloidal Solution = Dispersed phase + Dispersion medium.

→ Size of colloidal particles = 1 to 1000 nm.

Disperse Phase –: The phase which is distributed (or dispersed) through the medium is called disperse phase [DP].



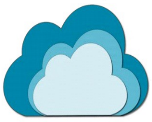
Dispersion Medium –: A medium in which colloidal particles are dispersed is called continuous phase or dispersion medium [DM].

For example –: Gold sol → Gold particles are D.P. and water is DM.

Classification of Colloids

(i) On the basis of physical state of DP and DM :- [Most important]

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, jellies
Liquid	Liquid	Emulsion	Milk, hair cream, butter
Liquid	Gas	Aerosol	Fog, mist, cloud, insecticide sprays
Gas	Solid	Solid sol	Pumice stone, foam rubber
Gas	Liquid	Foam	Froth, whipped cream, soap lather




(ii) On the basis of interaction between DP and DM :- [CBSE 2013] [Delhi 2014C] (3M)

(2M)

Lyophilic Colloids	Lyophobic Colloids
(i) Lyophilic means liquid loving.	(i) Lyophobic means liquid hating.
(ii) Colloidal solution in which the particles of dispersed phase (solute) have great affinity for dispersion medium (solvent).	(ii) Colloidal solution in which the partic of the dispersed phase have no affinity for DM.
(iii) Example → Glue, gelatin, starch, protein with a suitable liquid.	(iii) Example → Solution of metals [Ag, Au → Gold sol.
(iv) It is a reversible sol means that if DM is seperated from DP, the sol can be reconstituted by simply mixing of DM and DP. [CBSE 2010] (1M)	(iv) It is an irreversible sol means that it can not prepared just by mixing of DP and DM. It can be prepared only by special methods.
(v) It is a stable colloid. It can not be precipitated easily.	(v) It is an unstable colloid. So this sol needs stabilising agent for preservatio

[CBSE 2014] (1M)

(iii) On the basis of types of particles of the D.P. :-

ⓐ **Multimolecular Colloids** -: on dissociation, a large no. of atoms or molecules of a substance aggregate together to form species having size in Colloidal range. The species thus formed are called multimolecular Colloid. Example → Gold sol and sulphur [S_8] sol.

[CBSE 2013] (1M) [Delhi 2013 / 2010]

ⓑ **Macromolecular Colloids** -: Macromolecules [polymers] in suitable solvents form solution in which the size of macromolecules may be in colloidal range. Such Systems are called macromolecular colloids.

Example → Polymers [like starch, cellulose, proteins, enzymes, polythene etc.]

(1M) [CBSE 2013 / Delhi 2012 / 2010]

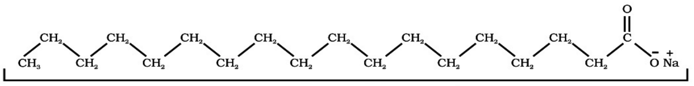
ⓒ **Associated Colloids** -: There are some substances which at low concentrations behave as normal strong electrolytes, but at higher concentrations exhibit colloidal behaviour due to formation of aggregates. [CBSE 2013 / 2019 | Delhi 2010 | 2012] (1M)

→ The aggregated particles are called micelles or associated colloids.

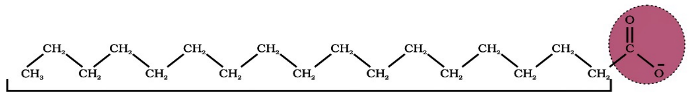
Example → Soap | Detergents

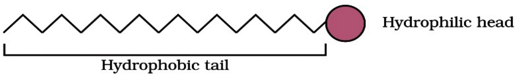
→ The formation of micelles takes place only above a particular temperature called Kraft temperature (T_k) and above a particular concentration called CMC means Critical micelle Concentration.

Mechanism of micelle formation —:



Sodium stearate ($C_{17}H_{35}CO\bar{O}\ \overset{+}{Na}$)





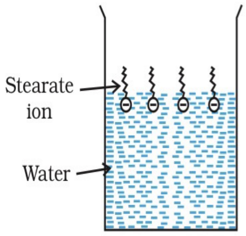
→ To understand the mechanism, let us take an example of soap solution.

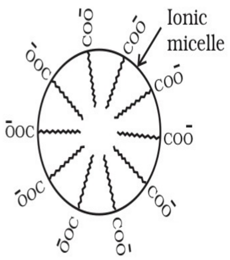
→ Soap : Sodium or potassium stearate

→ Sodium stearate has two parts

(i) Hydrophobic part [water repelling] : A long hydrocarbon chain (Non-polar tail)

(ii) Hydrophilic part [water loving] : $-COO^-$ group (polar-ionic head) [$C_{17}H_{35}^-$]



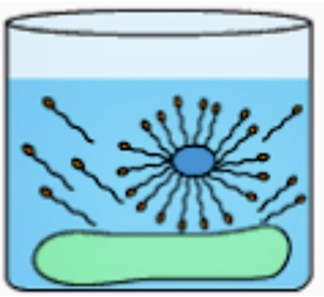


→ The $C_{17}H_{35}COO^-$ ions are present on the surface with their COO^- group in water and the hydrocarbon chains [$C_{17}H_{35}$] staying away from it and remain at the surface.

→ But at CMC, the anions are pulled into the bulk of solution and aggregate to form a spherical shape with their hydrocarbon chains pointing towards the centre of sphere with COO^- part remaining outward on the surface of sphere. This spherical aggregate is known as ionic micelle.

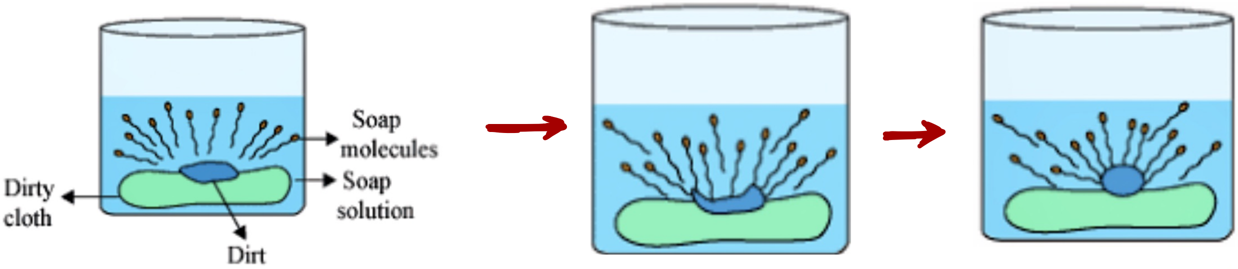
→ Detergents : Sodium laurylsulphate [$CH_3(CH_2)_{11}SO_4^{\ominus}Na^{\oplus}$]

Cleaning action of soap —: The cleaning action of soap is due to the fact that soap particles form micelle around the oil droplet in such a way that hydrophobic part of the stearate ions is in oil droplet and hydrophilic part projects out of the grease droplet. Because hydrophilic part is outside of oil droplet, so it can interact with water due to polarity.



→ The oil droplet surrounded by stearate ions is now pulled in water and removed from dirty surface.

[CBSE 2012]
(2M)



Preparation of colloids

ⓘ Chemical Methods –:

[a] Double decomposition –: $As_2O_3 + 3H_2S \longrightarrow As_2S_3(sol) + 3H_2O$

Arsenic sulphide sol

[b] Oxidation –: $SO_2 + 2H_2S \longrightarrow 3S + H_2O$

Sulphur sol

[c] Reduction –: $2AuCl_3 + 3HCHO + 3H_2O \longrightarrow 2Au + HCOOH + 6HCl$

Gold Sol

[Delhi 2013]
(2M)

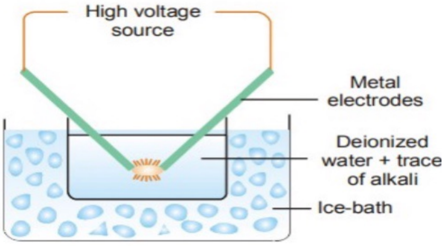
[d] Hydrolysis –: $FeCl_3 + 3H_2O \longrightarrow Fe(OH)_3 + 3HCl$

Ferric Hydroxide Sol

ⓘⓘ Bredig's Arc Method –: [Electrical Disintegration]

By using electric arc, we can disintegrate (vapourise) the metal electrode [gold, silver, planinum etc.] which then condensate to form particles of colloidal size.

→ This process involves dispersion as well as condensation.



ⓘⓘⓘ Peptization –:

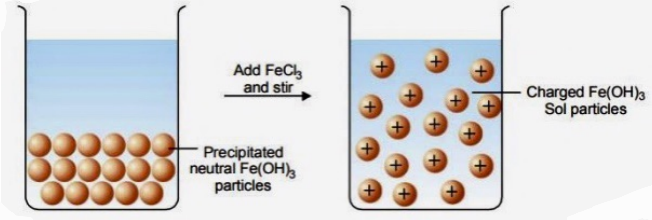
[CBSE 2010 | 2013
Delhi 2011/2013/2014C]
(1M)

Process of converting a precipitate into colloidal sol, by shaking it with DM in presence of a small amount of electrolyte.

→ The electrolyte used for this purpose is called peptizing agent.

→ During peptization the ppt adsorbs one of the ions of electrolyte on its surface. This causes the developement of positive or negative charge on ppt, which ultimately break up into smaller particles of size of a colloid.

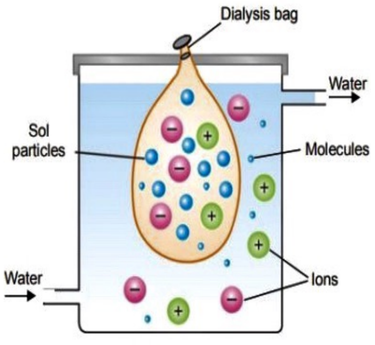
ppt + Electrolyte = Colloidal Solution



Purification of Colloidal solution

ⓘ **Dialysis** –: It is process of removing a dissolved substance from a colloidal solution by means of diffusion through suitable membrane. [CBSE 2011] (1M)

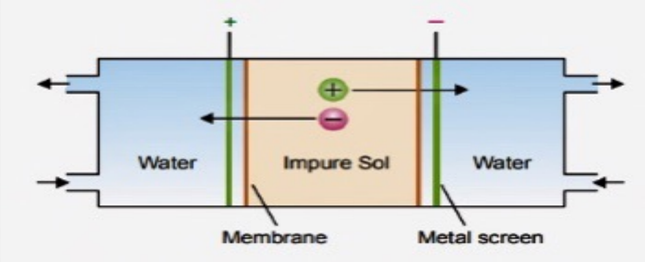
→ True solution can pass through this membrane but not colloidal particles.



→ A bag of semipermeable membrane containing the colloidal solution is suspended in a vessel through which fresh water is continuous flowing. The molecules and ions diffuse through membrane into the outer water and pure colloidal solution is left behind.

(ii) Electro-dialysis -:

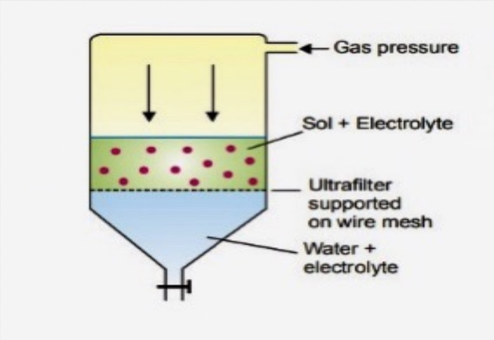
→ Dialysis can be made faster by applying an electric field.



(iii) Ultra-filtration -:

Ordinary filter paper have very large pore size. So it can pass both impurities and colloidal particles.

→ In such condition, we use ultrafilter paper which is designed in such a way that it can allows only the true solution to pass through. The pure colloid left on filter paper.



Properties of colloidal solutions

(i) Optical Property [Tyndall effect]

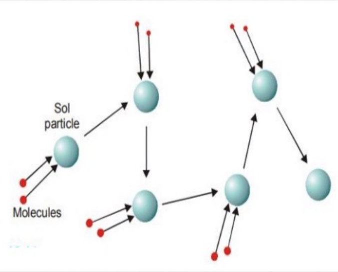
→ Scattering of light by colloidal particles is called Tyndall effect. [CBSE 2015C | 2011 | Delhi 2014C] 1M

→ This scattering of light illuminates the path of beam in colloidal solution.

Condition for Tyndall effect -: (i) size of the colloidal particles should be approximately similar to the wavelength of light used.
(ii) The difference in refractive indices of D.P. and D.M. should be large.

→ As the size of particles changes colour of colloidal solution changes.

(ii) Brownian Motion -: [Kinetic Property]



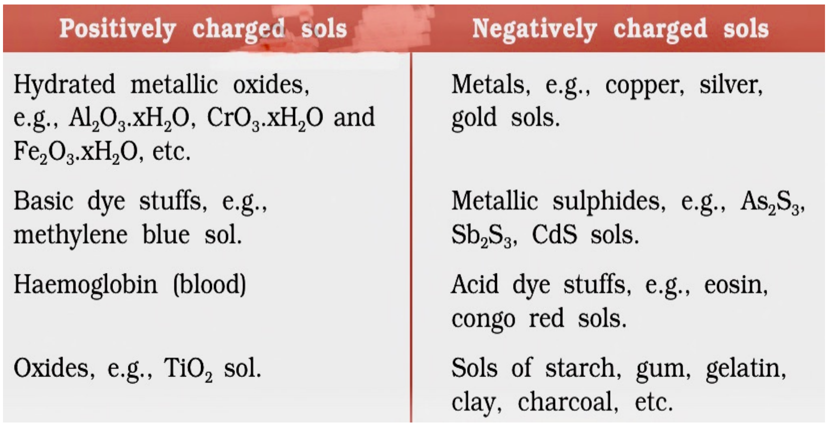
→ Continuous random motion | zig-zag motion of the colloidal particles is known as Brownian motion.

→ The Brownian movement has been explained to be due to the unbalanced bombardment of the particles by the molecules of the DM.

→ This motion stabilizes the colloidal solution as it does not allow to the DP to settle down.

(iii) Electrical Properties —:

Charge on colloidal Particles —: Colloidal particles always carry an electric charge. The nature of this charge is same for all the particles in a given colloidal solution.

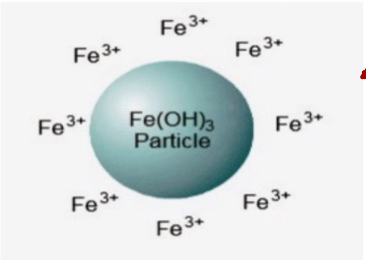


Positively charged sols	Negatively charged sols
Hydrated metallic oxides, e.g., $Al_2O_3.xH_2O$, $CrO_3.xH_2O$ and $Fe_2O_3.xH_2O$, etc.	Metals, e.g., copper, silver, gold sols.
Basic dye stuffs, e.g., methylene blue sol.	Metallic sulphides, e.g., As_2S_3, Sb_2S_3, CdS sols.
Haemoglobin (blood)	Acid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

→ Preferential adsorption of ions create charge on colloidal particles.

→ The charge on sol particles originates by selective adsorption of ions common to the particles from the dispersion medium.

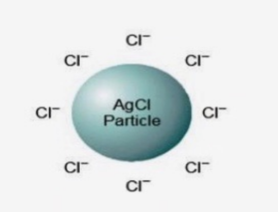
$Fe(OH)_3 + Fe^{+3} \longrightarrow Fe(OH)_3 / Fe^{+3}$



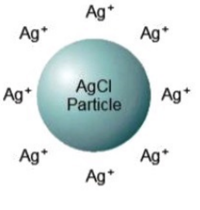
→ In some cases, particles may adsorb the anions or cations whichever are in excess and acquire the corresponding charge.

→ $AgNO_3 + \underset{(Excess)}{KCl} \longrightarrow AgCl \xrightarrow{KCl} AgCl / Cl^-$

→ $\underset{(Excess)}{AgNO_3} + KCl \longrightarrow AgCl \xrightarrow{AgNO_3} AgCl / Ag^+$



$AgCl / Cl^-$

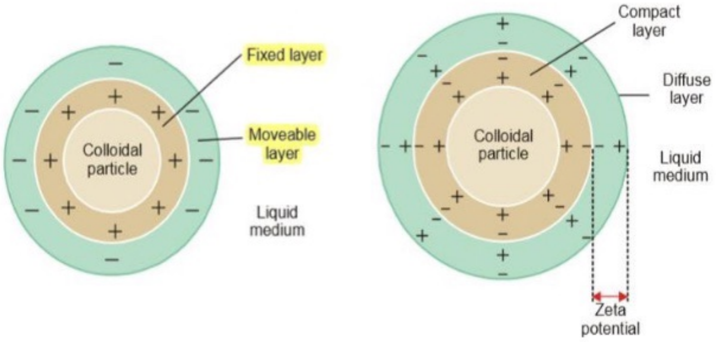


$AgCl / Ag^+$

Zeta Potential [Electrokinetic Potential]

Potential difference between fixed layer and diffused layer = Zeta Potential.

[CBSE 2015C] (1M)



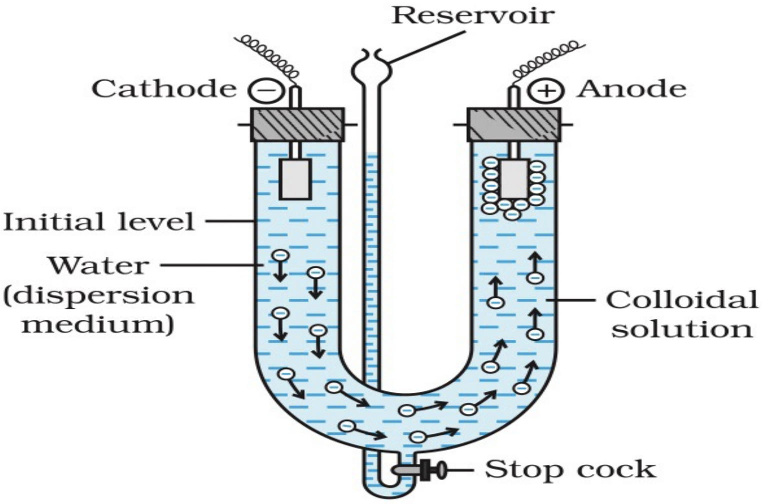
Electrophoresis —: The existance of charge on colloidal particles is confirmed by electrophoresis experiment.

[Delhi 2011] [Delhi 2015C] (1M)

→ The movement of sol particles under electric potential is called cataphoresis or electrophoresis.

→ ⊕ve particles moves towards cathode.

→ ⊖ve particles moves towards anode.



ⓘⓥ **Coagulation [Precipitation] —:** The process of settling of colloidal particles is called coagulation of the sol.

→ The stability of lyophobic sols is due to the presence of charge on colloidal particles. If charge is removed by some method, the particles will come nearer to each other to form aggregates and settle down under the force of gravity.

→ Coagulation of lyophobic sols can be carried out by following ways —: [Delhi 2012 | CBSE 2010] (1M)

① By Electrophoresis ③ By addition of electrolyte

② By Boiling ④ By mixing of two oppositively charged sols.

Hardy - Schulze Law —: The precipitating effect of an ion on DP of opposite charge increases with charge of ion.

→ Coagulation Power ∝ Charge on ion

→ For coagulation of $Fe(OH)_3$ sol : order of coagulation power : $[Fe(CN)_6]^{4-} > SO_4^{2-} > Cl^-$

→ For ⊖vely charged sol : order of coagulation power : $Al^{+3} > Ba^{+2} > Na^+$

Coagulation Value —: Minimum concentration of an electrolyte [milimoles per litre] required to cause precipitation of a sol is called coagulation value.

→ Coagulation Power ∝ $\frac{1}{\text{Coagulation Value}}$

Protection of colloids —: Lyophilic sols are more stable than lyophobic sols, because lyophilic sols are extensively solvated by DM. [Delhi 2015] (1M)

→ Due to its stability, lyophilic sols are used to protect the lyophobic sols from precipitation [coagulation]. Lyophilic sol form a protective layer around lyophobic sol particles and thus protect from electrolyte.

Gold Number —: Protective power of lyophilic sol is expressed in term of gold no.

→ "The no. of miligrams of a hydrophilic colloid that will just prevent the precipitation of 10 ml of a gold sol, on the addition of 1 ml of 10% NaCl solution."

$$\boxed{\text{Protecting Power} \propto \frac{1}{\text{Gold Number}}}$$

Emulsions

[CBSE 2012 / 2013 / 2014 / Delhi 2010]
2015C

→ These are liquid - liquid colloidal systems.

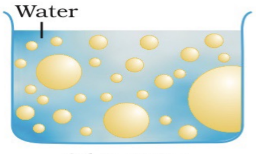
→ In otherwords an emulsion may be defined as a dispersion / distribution of finely divided liquid droplets in another liquid.

There are two types of emulsions.

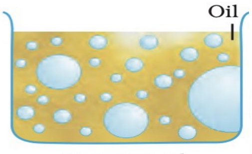
ⓘ Oil in water type [O/W type]

DP → Oil

DM → Water



Oil in water



Water in oil

Example → Milk / Cream / Soap / Gums

ⓘⓘ Water in oil type [W/O type]

DP → Water

DM → Oil

Example → Heavy metal salts of fatty acids.

Emulsifying Agent -: Water and oil are immisible and they form unstable emulsions
[Delhi 2010] (1M) Or sametime they seperate in two layers. To stablise the emulsions and to make them homogeneous, we add emulsifying agent.

Example → Soap / Detergents : Emulsifier

Casein (protein) in milk : Emulsifying agent.

→ Emulsions can be broken into constituent liquids by heating, freezing and centrifuging etc. This process is called De- emulsification.

(1M)
[CBSE 2019 / Delhi 2015]

Question :- Leather gets hardend after tanning, why?

Answer -: Because colloidal nature of animal - skin having positively charged particles whereas tannin consists of negatively charged colloidal particles, which when combine leather get hardened.

(1M)

Question -: Why are medicines more effective in colloidal state? [Delhi 2019]

Answer -: Because they have large surface area per unit mass. So they are easily assimilated in the body.

Question -: Some substance can act both as Colloid and crystalloids. Explain?

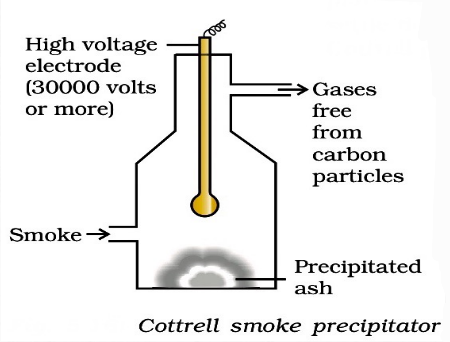
[Delhi 2012C / 2013C]

Answer -: When size of the particle lies between 1 to 1000 nm ⇒ Colloid. (1M)

When size of the particle is less than 1 nm (true solution range) ⇒ Crystalloid

Example → NaCl in water : Colloid ; NaCl in benzene : Crystalloid.

Applications of colloids –: [CBSE 2012C] (1M)



Cottrell smoke precipitator

(i) Electrical precipitation of smoke :– Smoke is a colloidal solution of solid particles such as carbon arsenic compounds, dust etc, in air.

→ Cottrell Precipitator –: a chamber containing plates having a charge opposite to that carried by smoke particles. The particles on coming in contact with these plates lose their charge and get precipitated.

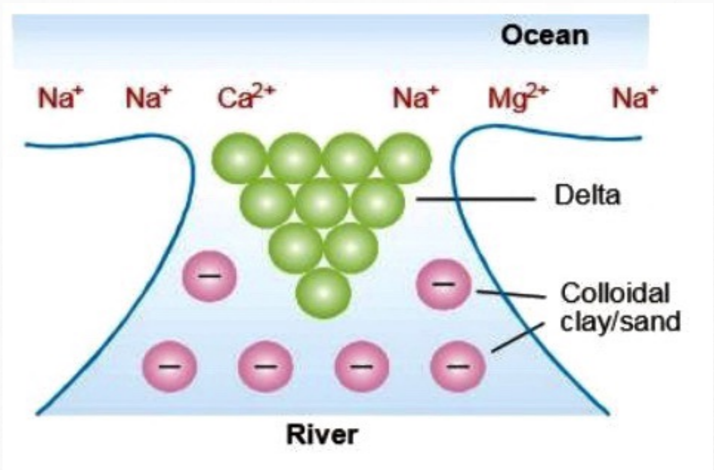
(ii) coagulation of blood –: blood is a colloidal particle which get precipitated by using alum (electrolyte).

Formation of Delta –: (1M) [CBSE 2015]

→ Due to precipitation of clay (which is colloidal in nature), delta's are formed at junction of river and sea.

Question –: Why is a finely divided substance more effective as an adsorbent.?

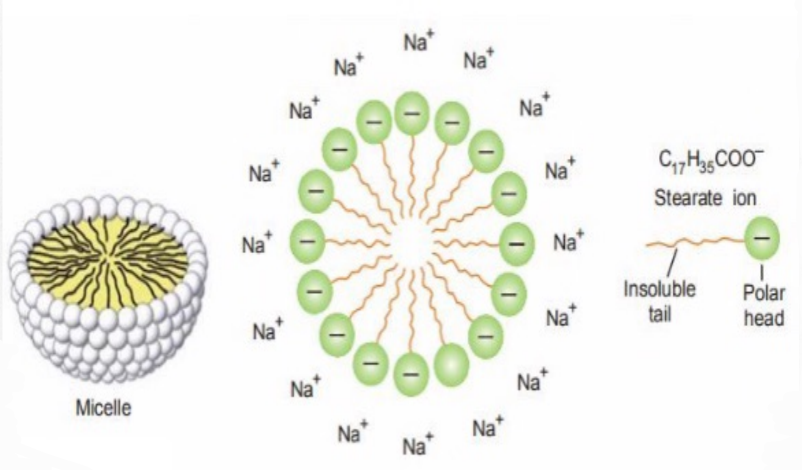
Answer –: finely divided substance has more surface area, so more adsorption occurs. [Delhi 2010C | CBSE 2011C] (1M)



Delta Formation

All the Best !! :)

Micelle Formation



$C_{17}H_{35}COO^-$