

Subject: Physical Chemistry, paper III(A)

Topic: Colloids

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Properties of colloids: (1) Kinetic properties, (2) Optical properties, (3) Electrical properties

(1) **Kinetic properties:** Kinetic properties are related to the motion of the particles within the dispersion medium.

Brownian movement: It is also termed as Brownian motion and is named after its discoverer Robert Brown (a Botanist.). Brownian movement is the zig-zag motion of colloidal particles suspended in a fluid (a liquid or a gas) resulting from their random collision with molecules of the dispersion medium (solvent). The forces are unequal in different directions. Hence it causes the particles to move in a zig-zag way.

- The velocity of particles increases with decreasing particle size and viscosity.

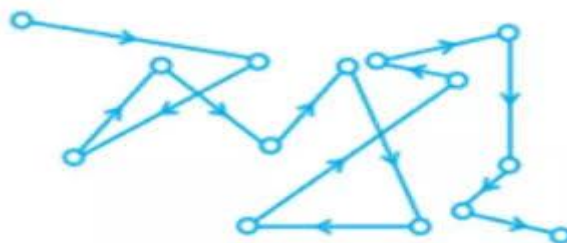


Figure: Brownian movement of particles

(2) **Optical properties:**

Light scattering (Tyndall effect): When a beam of light pass through a colloidal sol placed in dark, the path of light through the colloidal solution is clearly visible due to scattering of light by the particles in a colloid. This phenomenon is called Tyndall Effect. This effect was observed by Tyndall in 1869. The same effect is noticed when a beam of light enters a dark room through a slit and becomes visible. This happens due to the scattering of light by particles of dust in the air.

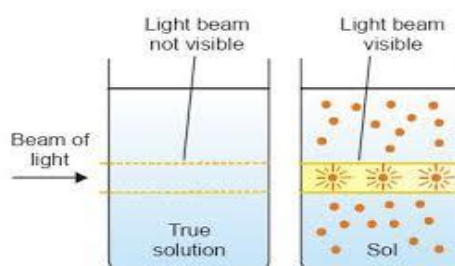


Figure: Light scattering (Tyndall effect)

- Tyndall effect is not exhibited by true solutions. This is because the particles (ions or molecules) present in a true solution are too small and hence do not scatter light and appear clear but colloidal dispersions contain opaque particles that do scatter light and thus appear turbid. Thus, Tyndall effect can be used to distinguish a colloidal solution from a true solution.

Study material: For B.Sc. part-II (Hons.)

(3) Electrical properties: One of the most important properties of colloidal solutions is that colloidal particles possess a definite type of electrical charge. The particles of a colloidal solution are electrically charged and carry the same type of charge, either negative or positive. The colloidal particles repel each other and do not cluster together to settle down. The dispersion medium has an equal and opposite charge. Thus, the charge on colloidal particles is balanced by that of the dispersion medium and the colloidal solution as a whole is electrically neutral. Based on the nature of charge, the colloidal sols may be classified as positively charged and negatively charged sols.

- **Positively charged sols:** Metallic hydroxide sols e.g., $\text{Fe}(\text{OH})_3$, $\text{Al}(\text{OH})_3$, $\text{Cr}(\text{OH})_3$, etc., TiO_2 sol, haemoglobin, sols of basic dyes such as methylene blue etc.
- **Negatively charged sols:** Metal sols e.g., Au, Ag, Cu, Pt etc. sols, metal sulphide sols e.g., As_2S_3 , CdS etc. sols; starch sol, sols of acid dyes such as Congo red etc.

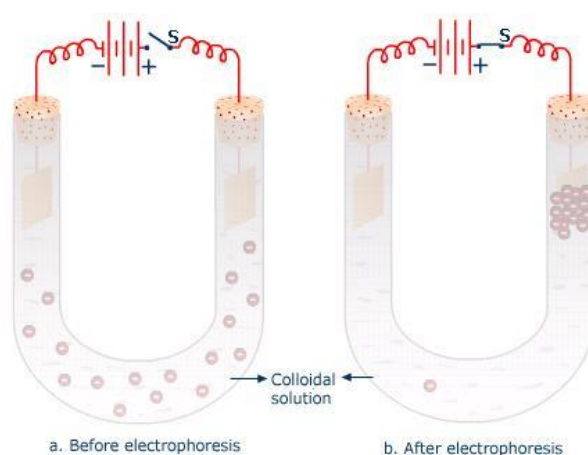
Origin of charge on colloidal particles is due to:

- (a) Preferential adsorption of cations or anions by colloidal particles.
- (b) Miscelles carry a charge on them.
- (c) During the formation of colloids especially by Bredig arc method, colloidal particles capture electrons and get charged.

The existence of charge on a colloidal particle is shown by a process called **electrophoresis**.

Electrophoresis:

Electrophoresis is a process which involves the movement of colloidal particles either towards cathode or anode under the influence of electrical field. The direction of movement of the colloidal particles is decided by the nature of charge present on them. If the colloidal particles carry positive charge, they move towards cathode when subjected to an electric field and vice versa.



- The property can be used to find the nature of charge carried by colloidal particles in a colloidal dispersion.

Electro-Osmosis: The movement of dispersion medium under the influence of an electric field in the situation when the movement of colloidal particles is prevented with the help of a suitable membrane.

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- The colloidal solution is placed between two partitions made by semi permeable membranes.
- The outer compartments consisting of platinum electrodes and side tubes are filled with water.
- On passing electric current, water level begins to rise in one of the side tubs and falls in the other.

We have already seen that the colloidal particles and dispersion medium carry charges which are equal but opposite in nature. Under the influence of an electric field, both have a tendency to move towards the oppositely charged electrodes. Semi permeable membranes do not allow the passage of colloidal particles. However, dispersion medium can pass through them. Therefore during electro-osmosis, colloidal particles are checked and it is the dispersion medium that moves towards the oppositely charged electrode.

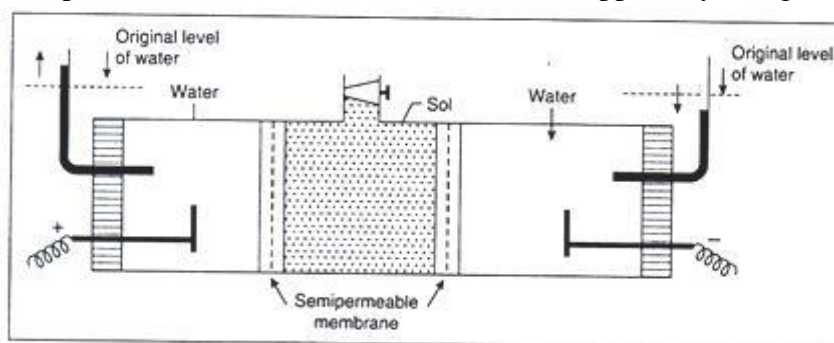


Figure: Electro-Osmosis

Origin of Charge on Colloidal Particles

Colloidal particles acquire charge due to the following reasons.

- **Due to dissociation of the adsorbed molecular electrolytes:** Colloidal particles have a strong tendency to adsorb reactant or product molecules. The molecules thus adsorbed on the surface of colloidal particles may undergo dissociation/ionization and may impart charge to them.

For example, during the preparation of sulphide sols (e.g., As_2S_3 sol), H_2S molecules get adsorbed on colloidal particles. H_2S molecules thus adsorbed undergo ionization and release H^+ ions into the medium. Consequently, colloidal particles are left with negative charge.

- **Due to the dissociation of molecules forming colloidal aggregates:** The molecules responsible for the formation of aggregates of colloidal dimensions may themselves undergo dissociation/ionisation resulting in the development of charge on the colloidal particles formed by their aggregation.

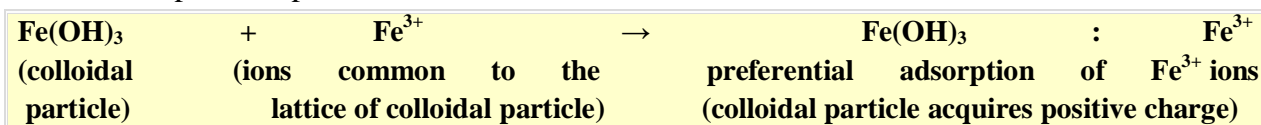
For example, the soap molecules (RCOONa) dissociate to give RCOO^- and Na^+ ions. RCOO^- ions aggregate together to form micelles which carry negative charge as explained earlier.

- **Due to preferential adsorption of ions from solutions:** The colloidal particles have a tendency to preferentially adsorb a particular type of ions from the solution. A colloidal

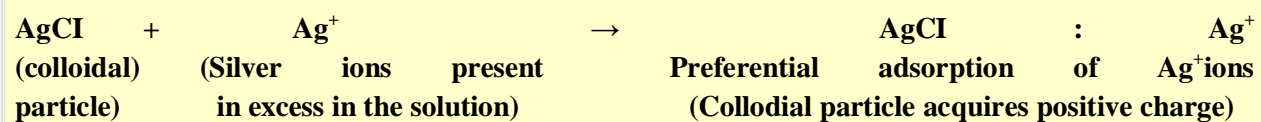
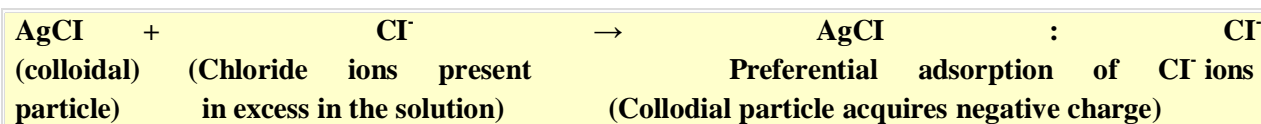
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particle usually adsorbs those ions which are in excess and are common to its own lattice. This preferential adsorption of a particular type of ions imparts a particular type of charge to colloidal particles.

For example, when a ferric hydroxide sol is prepared by the hydrolysis of ferric chloride in warm water, the colloidal particles of $\text{Fe}(\text{OH})_3$ formed have a tendency to adsorb preferentially the Fe^{3+} ions present in the solution. This is because Fe^{3+} ions are common to the lattice of $\text{Fe}(\text{OH})_3$ particle. The Fe^{3+} ions thus adsorbed impart positive charge to the colloidal particles present in the sol.



- Similarly, during the preparation of AgCl sol using excess of KCl solution, the Cl^- ions are preferentially adsorbed and the colloidal particles acquire negative charge. However, if an excess of AgNO_3 is used, Ag^+ ions get preferentially adsorbed and the colloidal particles acquire positive charge.



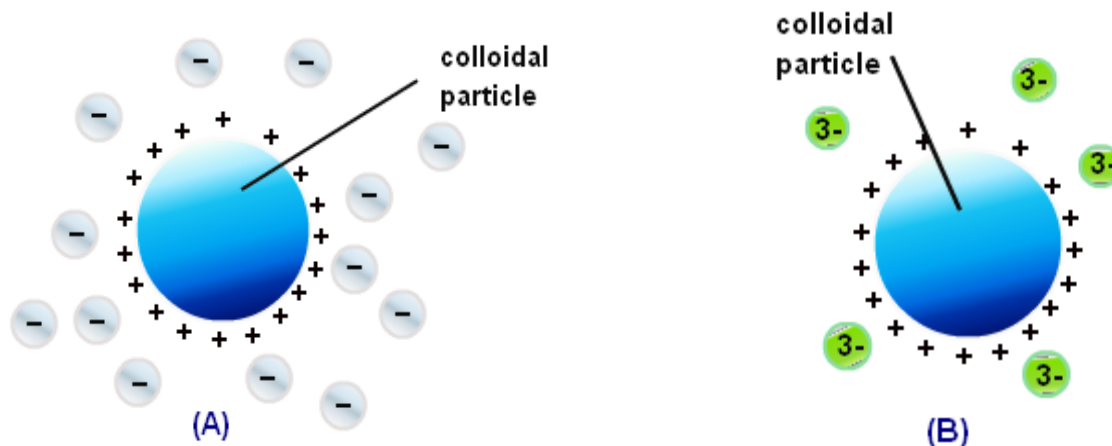
Electrokinetic potential: Electrokinetic potential is scientifically term as **Zeta potential**. zeta potential is the potential difference between the dispersion medium and the stationary layer of fluid attached to the dispersed particle. The zeta potential is a key indicator of the stability of colloidal dispersions. The magnitude of the zeta potential indicates the degree of electrostatic repulsion between similarly nearby charged particles in a dispersion medium. A high zeta potential will confer stability, i.e., the solution or dispersion will resist aggregation. When the potential is small, attractive forces may exceed this repulsion and the dispersion may break and flocculate. So, colloids with high zeta potential (negative or positive) are electrically stabilized while colloids with low zeta potentials tend to coagulate or flocculate.

Coagulation or Flocculation: The stability of a sol is due to the charge present on the colloidal particles. Due to similar charges, colloidal particles repel one another and are unable to combine together to form larger particles. However, if the charge on colloidal particles is destroyed, they are free to come nearer and grow in size. When the particles become sufficiently large, they get precipitated. This phenomenon is termed as coagulation or flocculation. Thus, Coagulation is the phenomenon involving the precipitation of a colloidal solution on addition of an electrolyte.

- The coagulation of colloidal solution can be achieved by the addition of an electrolyte.

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- It is to be noted that a small amount of electrolyte is necessary for the stability of a sol because the ions of the electrolyte get adsorbed on colloidal particles and impart them some charge. However, when an electrolyte is added in substantial amount the positively charged ions of the electrolyte neutralize the charge on colloidal particles and compel the sol to get coagulated.



However, the coagulation of colloidal solution can also be achieved by any of the following methods.

- By electrophoresis:** In electrophoresis, the charged colloidal particles migrate to the oppositely charged electrode and get discharged. This results in the coagulation of the colloidal solution.
- By mixing two oppositely sols:** When two sols carrying opposite charges are mixed together in suitable proportions, the colloidal particles of one sol neutralize the charge present on the particles of the other sol and both get coagulated.
- By persistent dialysis:** We have already seen that a small amount of electrolyte is essential to make a sol stable. When a sol is subjected to persistent dialysis, the traces of electrolyte also pass out through the membrane. In the absence of electrolyte, sol becomes unstable and gets coagulated.

Hardy-Schulze rule: The coagulation capacity of an electrolyte depends upon the valence of ion responsible for causing coagulation. As we have seen above, the ion responsible for causing coagulation is the one which carries charge opposite to that present on colloidal particles. For example, a positively charged sol gets coagulated by the negatively charged ions of the added electrolyte. From a study of the coagulation behavior of various electrolytes towards a particular sol, Hardy and Schulze suggested a general rule known as Hardy-Schulze rule. The rule can be stated as **“the greater is the valence of the oppositely charged ion of the electrolyte added to a colloidal solution, the faster is the coagulation of the colloidal solution.”**

- Thus, higher the charge on oppositely charged ion greater is its coagulating power. For example, the coagulation power of different cations for coagulating a negatively charged sol of As_2S_3 follows the order. $\text{Al}^{3+} > \text{Ba}^{2+} > \text{Na}^+$

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- Similarly, for the coagulation of a positively charged sol such as $\text{Fe}(\text{OH})_3$, the coagulating power of different anions follows the order. $[\text{Fe}(\text{CN})_6]^{4-} > \text{PO}_4^{3-} > \text{SO}_4^{2-} > \text{Cl}^-$

Flocculation value: The coagulating power of an electrolyte is usually expressed in terms of its flocculation value which may be defined as the minimum concentration (in millimoles per litre) of an electrolyte required to cause the coagulation of a sol.

- Smaller flocculation value indicates the greater coagulating power of the electrolyte. Thus,

$$\text{Coagulating power} \propto \frac{1}{\text{Flocculation value}}$$

Protective Colloids and Gold Number:

- Lyophobic sols such as those of metals (e.g. Au, Ag, Pt etc.) are not very stable in the sense that they get easily coagulated (precipitated) in the presence of an electrolyte. This poses a big problem in their storage and usage. Contrary to this, lyophilic sols are much more stable and do not get coagulated easily under similar conditions.
- It has been observed that in the presence of certain lyophilic colloids such as gum Arabic, gelatin, starch etc. the hydrophobic sols acquire greater stability towards coagulation, i.e. they get protected and do not get coagulated easily when an electrolyte is added.
- The process of protecting a lyophobic sol from being coagulated (precipitated) on addition of an electrolyte by the use of a lyophilic colloids is called protection and the lyophilic colloid used for purpose is called a protective colloid. For example, the addition of gelatin (a lyophilic colloid) to a gold sol (lyophobic sol) protects the latter from being coagulated on addition of sodium chloride solution.

Gold Number: The protective power a lyophilic colloid is usually expressed in terms of a number called gold number introduced by Zsigmondy (1901). **The gold number of a protective colloid is its minimum amount in milligrams which is just sufficient to prevent the coagulation of 10 ml of a gold sol on the addition of 1 mL of 10% sodium chloride solution.**

- The smaller the value of gold number, the greater is the protective power of the protective colloid.

Emulsions: Emulsions are colloidal solutions in which both the dispersed phase and dispersion medium are liquids.

Emulsion are of two kinds :

(a) ***Oil-in-water emulsion*** : Here the dispersed phase is oil while the dispersion medium is water. Example: Vanishing cream, Milk (in milk liquid fats are dispersed in water).

(b) ***Water-in-oil emulsion*** : Here dispersed phase is water and dispersion medium is oil. Examples: Butter, cod- liver oil, cold creams.

- The liquids forming emulsion i.e. oil and water will separate out on keeping as they are immiscible. Therefore an emulsifying agent or emulsifier is added to stabilise the emulsion.

Soap is a common ***emulsifier***. The preparation of emulsion in the presence of an emulsifier is called emulsification..

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Applications of Emulsions - Emulsions play very important role in our daily life. Some of the common applications are given below :

1. The cleansing action of soap and synthetic detergents for washing clothes, bathing etc is based upon the formation of oil in water type emulsion.
2. Milk is an emulsion of fat in water. Milk cream and butter are also emulsions.
3. Various cold creams, vanishing creams, body lotions etc. are all emulsions.
4. Various oily drugs such as cod liver oil are administered in the form of emulsion for their better and faster absorption. Some ointments are also in the form of emulsions.
5. The digestion of fats in the intestine occurs by the process of emulsification.
6. Emulsions are used for concentrating the sulphide ores by froth flotation process. Finely powdered ore is treated with an oil emulsion and the mixture is vigorously agitated by compressed air when the ore particles are carried to the surface and removed.

Gels: Gels are the type of colloids in which the dispersed phase is a liquid and the dispersion medium is a solid. Examples: Cheese, jelly, boot polish. Gels are divided in two categories elastic gels and non-elastic gels. Elastic gels are reversible. When partly dehydrated on losing water, they change back into the original form on addition of water. The non-elastic gels are not reversible.

Micelles: A micelle is an aggregate of surfactant molecules dispersed in a liquid colloid. The structures contain hydrophilic/polar region (head) and hydrophobic/nonpolar region (tail). Micelles are formed in aqueous solution whereby the polar region faces the outside surface of the micelle and the nonpolar region forms the core.

Assignment

Question 1: Which of the following alternatives represents the correct order of coagulation power of ions?

- (a) $\text{Na}^+ > \text{Al}^{3+} > \text{Ba}^{2+}$ (b) $\text{Ba}^{2+} > \text{Al}^{3+} > \text{Na}^+$
(c) $\text{Ba}^{2+} > \text{Na}^+ > \text{Al}^{3+}$ (d) $\text{Al}^{3+} > \text{Ba}^{2+} > \text{Na}^+$

Question 2: When an intense converging beam of light is passed through a colloidal solution kept in dark, the path of the beam gets illuminated with a bluish light. This phenomenon is called

- (a) Tyndrall effect (b) Coagulation of colloids
(c) Peptization (d) Dispersion of light

Question 3: Which of the following alternatives does not form a positively charged sol ?

- (a) $\text{Fe}(\text{OH})_3$ (b) $\text{Al}(\text{OH})_3$
(c) TiO_2 (d) Cd

Question 4: The minimum amount of any colloid in milligrams which is just sufficient to prevent the coagulation of 10 ml of a gold sol on the addition of 1 mL of 10% sodium chloride solution is called its

- (a) Gold number (b) Coagulation value
(c) Flocculation value (d) Osmotic potential