
Surface Chemistry - Part 4

Objectives

After going through this lesson, the learners will be able to understand the following:

- Describe the Colligative, Optical, Physical, Mechanical and Electrical Properties of Colloids
- Understand the Important Processes such as Tyndall Effect, Brownian Movement and Electrophoresis
- Know about the Protection of Colloids
- Classify Emulsions and Describe their Preparation and Properties
- List the Uses of Colloids

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- Introduction
- Properties of Colloids
- Coagulation or Precipitation or Flocculation
- Electrophoresis
- Protection of Colloids
- Emulsions
- Colloids around us
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Introduction

In the earlier module, you have studied about the preparation and purification of colloids. In this module, we will discuss the properties and protection of colloids. Moreover, important processes such as electrophoresis, coagulation and protection of colloids will also be discussed. We shall also discuss about emulsions—a class of colloids. These find extensive applications in food processing, detergent, pharmaceuticals and plastics. Some examples and applications of colloids are also discussed.

Properties of Colloids

Various properties exhibited by the colloids are described below:

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- i. **Physical Property:** Although heterogeneous, the particles of colloids cannot be separated by filtration. Colloids are generally stable.

 - ii. **Colligative Property:** Colloidal particles being bigger aggregates, the number of particles in a colloid 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.

 - iii. **Optical Property**
 - a. **Tyndall Effect:** If a homogeneous solution placed in dark is observed in the direction of light, it appears clear and, if it is observed from a direction at right angles to the direction of light beam, it appears perfectly dark. Colloids viewed in the same way may also appear reasonably clear or translucent by the transmitted light but they show a mild to strong opalescence, when viewed at right angles to the passage of light, i.e., the path of the beam is illuminated. This effect was first observed by Faraday and later studied in detail by Tyndall and is termed as **Tyndall effect**. The bright cone of the light is called Tyndall cone (Fig.1). 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 (Fig.2).

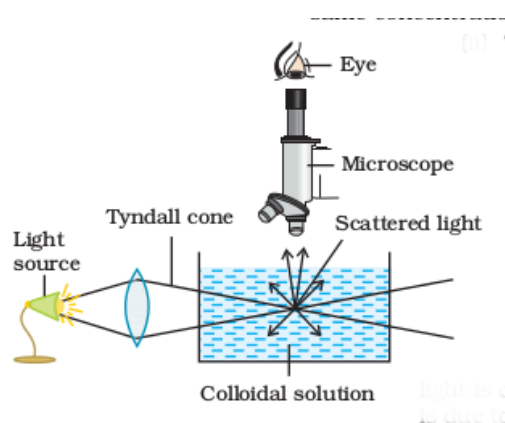


Fig.1: Tyndall effect

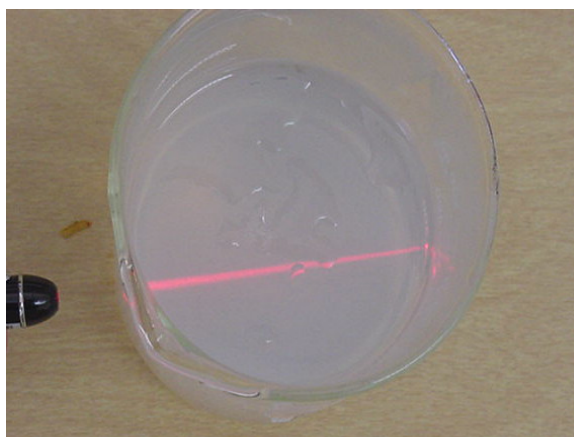


Fig. 2: Tyndall effect

Source: https://pk014.k12.sd.us/Physical%20science/chapter%2022/light_colloid.jpg

Tyndall effect can be observed during the projection of picture in the cinema hall due to scattering of light by dust and smoke particles present there. 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.

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

- b. **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. For example, a mixture of milk and water appears blue when viewed by the reflected light and red when viewed by the transmitted light. Finest gold sol is red in colour; as the size of particles increases, it appears purple, then blue and finally golden.

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- iv. **Mechanical Property - Brownian movement:** When colloids are viewed under a powerful ultramicroscope, the colloidal particles appear to be in a state of continuous zig-zag motion all over the field of view. This motion was first observed by the British botanist, Robert Brown, and is known as the **Brownian movement** (Fig.3). This motion is independent of the nature of the colloid but 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 been explained to be due to the unbalanced bombardment of the particles by the molecules of the dispersion medium. The Brownian movement has a stirring effect which does not permit the particles to settle and thus, is responsible for the stability of sols.



Fig.3: Brownian movement

- v. **Electrical Property: Charge on colloidal particles:** Colloidal particles always carry an electric charge. The nature of this charge is the same on all the colloidal particles in a given colloid and may be either positive or negative. The molecules of the dispersion medium have equal but opposite charge so that the system as a whole remains neutral. The colloidal particles repel each other as they carry the same charge, and do not aggregate together. Hence the sol as a whole remains stable, and the colloidal particles never settle down. A list of some common sols with the nature of charge on their particles is given below (Table 1):

Table 1: Common sols with nature of charge on their particles

Positively charged sols	Negatively charged sols
Hydrated metallic oxides, e.g., $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, $\text{CrO}_3 \cdot x\text{H}_2\text{O}$ and $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, 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.

The charge on the sol particles is due to one or more reasons, viz., due to electron capture by sol particles during electro dispersion of metals, due to preferential adsorption of ions from solution and/or due to formulation of electrical double layer.

Preferential adsorption of ions is the most accepted reason. The sol particles acquire positive or negative charge by preferential adsorption of positive or negative ions. When two or more ions are present in the dispersion medium, usually preferential adsorption of the ion common to the colloidal particle takes place. This can be explained by taking the following examples:

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



Negatively charged

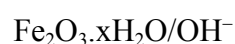


Positively charged

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

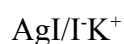


Positively charged



Negatively charged

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



The combination of the two layers of opposite charges around the colloidal particle is called **Helmholtz electrical double layer**. According to modern views, the first layer of ions is firmly held and is termed **fixed layer** while the second layer is mobile which is termed

diffused layer. Since separation of charge is a seat of potential, the charges of opposite signs on the fixed and diffused parts of the double layer results in a difference in potential between these layers. This potential difference between the fixed layer and the diffused layer of opposite charges is called the **electrokinetic potential or zeta potential**.

The presence of equal and similar charges on colloidal particles is largely responsible for providing stability to the colloidal solution, because the repulsive forces between charged particles having the same charge prevent them from coalescing or aggregating when they come closer to one another.

Electrophoresis

The existence of charge on colloidal particles is confirmed by an electrophoresis experiment using the apparatus as shown in the figure. When electric potential is applied across two platinum electrodes dipping in a colloidal solution, the colloidal particles move towards one or the other electrode. The movement of colloidal particles under an applied electric potential is called **electrophoresis**. Positively charged particles move towards the cathode while negatively charged particles move towards the anode (Fig.4).

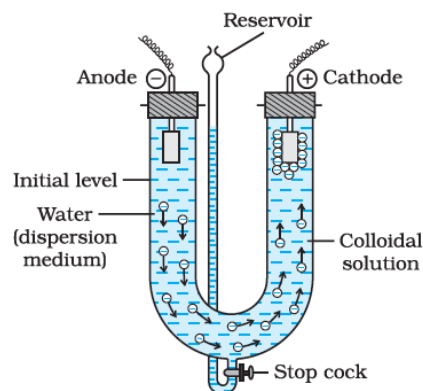


Fig.4: Electrophoresis

When electrophoresis, i.e., movement of particles is prevented by some suitable means, it is observed that the dispersion medium begins to move in the opposite direction. This phenomenon is termed **electroosmosis**.

Coagulation or Precipitation or Flocculation

The stability of the lyophobic sols is due to the presence of charge on colloidal particles. If, somehow, the charge is removed, the particles will come nearer to each other to form

aggregates (or coagulate) and settle down under the force of gravity. The process of settling of colloidal particles is called **coagulation** or **flocculation** of the sol.

The coagulation of the lyophobic sols can be carried out in the following ways:

- i. By electrophoresis: The colloidal particles move towards oppositely charged electrodes, get discharged and coagulated.
- ii. By mixing two oppositely charged sols: Oppositely charged sols when mixed in almost equal proportions, neutralise their charges and get partially or completely coagulated. Mixing of hydrated ferric oxide (+ve sol) and arsenious sulphide (-ve sol) bring them in coagulated forms. This type of coagulation is called mutual coagulation.
- iii. By boiling: When a sol is boiled, the adsorbed layer is disturbed due to increased collisions with the molecules of dispersion medium. This reduces the charge on the particles and ultimately leads to settling down of coagulated particles.
- iv. By persistent dialysis: On prolonged dialysis, traces of the electrolyte present in the sol are removed almost completely and the colloids become unstable and ultimately coagulate.
- v. By addition of electrolytes: When excess of an electrolyte is added, the colloidal particles are coagulated. The reason is that colloids interact with ions carrying a charge opposite to that present on themselves. This causes neutralisation leading to their coagulation. The ion responsible for neutralisation of charge on the particles is called the **coagulating ion**. A negative ion causes the coagulation of positively charged sol and vice versa.

It has been observed that, generally, the greater the valence of the coagulating ion added, the greater is its power to cause coagulation. This is known as Hardy-Schulze rule. In the coagulation of a negative sol, the coagulating power is in the order:



Similarly, in the coagulation of a positive sol, the flocculating power is in the order:



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

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 (i) by adding an electrolyte and / or (ii) 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.

Protection of Colloids

Lyophilic sols are more stable than lyophobic sols. This is due to the fact that lyophilic colloids are extensively solvated, i.e., colloidal particles are covered by a sheath of the liquid in which they are dispersed.

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**. The protective power of lyophilic colloid is expressed in terms of “Gold number”. It is defined as the minimum amount of protective colloid in milligrams which prevents a color change from red to violet of 10 ml **gold sol** by the addition of 1 ml of 10%NaCl solution. The more the gold number, the lesser will be the protective power of the lyophilic colloid.

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 (Fig.5).

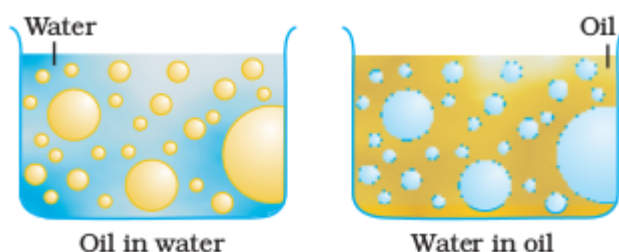


Fig.5: Types of emulsions

- i. Oil dispersed in water (O/W type) and

ii. Water dispersed in oil (W/O type).

In the first system, water acts as a dispersion medium. Examples of this type of emulsion are milk and vanishing cream. In milk, liquid fat is dispersed in water. In the second system, oil acts as a dispersion medium. Common examples of this type are butter and cream.

Emulsions of oil in water are unstable and sometimes they separate into two layers on standing. For stabilization of an emulsion, a third component called emulsifying agent is usually added. The emulsifying agent forms an interfacial film between suspended particles and the medium. The principal emulsifying agents for O/W emulsions are proteins, gums, natural and synthetic soaps, etc., and for W/O, heavy metal salts of fatty acids, long chain alcohols, etc.

Emulsions can be diluted with any amount of the dispersion medium. On the other hand, the dispersed liquid, when mixed, forms a separate layer. The droplets in emulsions are often negatively charged and can be precipitated by electrolytes. They also show Brownian movement and Tyndall effect. Emulsions can be broken into constituent liquids by heating, freezing, centrifuging, etc.

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:

- a. **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.
- b. **Fog, mist and rain:** When a large mass of air containing dust particles is cooled below its dew point, the moisture from the air condenses on the surfaces of these particles forming fine droplets. These droplets being colloidal in nature continue to float in air in the form of mist or fog. Clouds are aerosols having small droplets of water suspended in air. On account of condensation in the upper atmosphere, the colloidal droplets of water grow bigger and bigger in size, till they come down in the form of rain. Sometimes, the rainfall occurs when two oppositely charged clouds meet.

It is possible to cause artificial rain by throwing electrified sand or spraying a sol carrying charge opposite to the one on clouds from an aeroplane.

- c. **Food articles:** Milk, butter, halwa, ice creams, fruit juices, etc., are all colloids in one form or the other.
- d. **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.
- e. **Soils:** Fertile soils are colloidal in nature in which humus acts as a protective colloid. On account of colloidal nature, soils adsorb moisture and nourishing materials.
- f. **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 in sea water coagulate the colloidal solution of clay resulting in its deposition leading to the formation of delta.

Applications of Colloids

- i. **Colloids are widely used in the industry.**

Following are some examples:

Electrical precipitation of smoke: Smoke is a colloidal solution of solid particles such as carbon, arsenic compounds, dust, etc., in air. The smoke, before it comes out from the chimney, is led through 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. The particles thus settle down on the floor of the chamber. The precipitator is called the **Cottrell precipitator** (Fig.6).

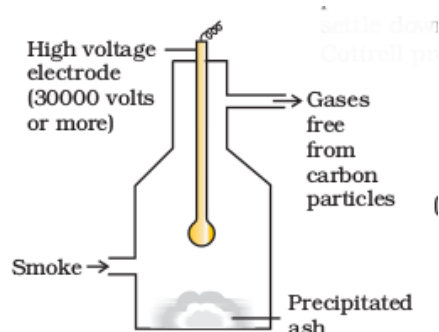


Fig.6: Cottrell smoke precipitator

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- 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.
 - iii. **Medicines:** Many medicines are colloidal in nature. For example, argyrol is a silver sol used as an eye lotion. Colloidal antimony is used in curing kala azar. 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.
 - iv. **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.
 - v. **Cleansing action of soaps and detergents:** This has already been described.
 - vi. **Photographic plates and films:** Photographic plates or films are prepared by coating an emulsion of the light sensitive silver bromide in gelatin over glass plates or celluloid films.
 - vii. **Rubber industry:** Latex is a colloidal solution of rubber particles which are negatively charged. Rubber is obtained by coagulation of latex.
 - viii. **Industrial products:** Paints, inks, synthetic plastics, rubber, graphite lubricants, cement, etc., are all colloidal solutions.

Intext Questions

1. What modification can you suggest in the Hardy Schulze law?
2. Why is it essential to wash the precipitate with water before estimating it quantitatively?

Summary

Colloids exhibit striking colligative, physical, mechanical, optical and electrical properties. A very important optical property is the Tyndall effect and it is due to the fact that colloidal particles scatter light in all directions in space. When colloids are viewed under a powerful ultramicroscope, the colloidal particles appear to be in a state of continuous zig-zag motion all over the field of view. This movement of colloidal particles is known as Brownian

movement. It is a significant mechanical property of colloids. The movement of colloidal particles under an applied electric potential is called electrophoresis. When electrophoresis, i.e., movement of particles, is prevented by some suitable means, it is observed that the dispersion medium begins to move in the opposite direction. This phenomenon is termed electroosmosis. The process of changing the colloidal particles in a sol into the insoluble precipitate by addition of some suitable electrolytes is known as coagulation. Emulsions are colloidal systems in which both dispersed phase and dispersion medium are liquids. These can be of: (i) oil in water type and (ii) water in oil type. The process of making emulsion is known as emulsification. To stabilize an emulsion, an emulsifying agent or emulsifier is added. Soaps and detergents are most frequently used as emulsifiers. Colloids find several applications in industry as well as in daily life.