**Classification of Colloids**

- Based on the physical state of dispersed phase and dispersion medium

**Dispersed phase**

- Gas → dispersion medium
  - Gas (one phase system)
  - Liquid: Foam (soap, whipped cream)
  - Solid: Solid Foam (pumic stone, styrene rubber)
- Liquid → dispersion medium
  - Gas: Aerosol (fog, clouds, mists)
  - Liquid: Emulsions (milk, emulsified oil)
  - Solid: Gel (cheese, butter, boot polish)
- Solid → dispersion medium
  - Gas: Aerosol (smoke, volcanic dust)
  - Liquid: Sols (paints, ink)
  - Solid: Solid sols (ruby, glass, some gemstones)

- Depending on the nature of interaction between dispersed phase and dispersion medium colloidal systems are divided into two classes:
  - Lyophilic colloids
  - Lyophobic colloids

| Property | Lyophilic colloids | Lyophobic colloids |
|---|---|---|
| Interaction | Strong interaction between dispersed phase and medium | Weak interaction between dispersed phase and medium |
| Preparation | Easy-by heating or warming | Special method required |
| Reversibility | Reversible | Irreversible |
| Stability | More stable | Less stable |
| Viscosity | Higher than medium | Same as medium |
| Surface tension | Lower than medium | Same as medium |
| Action of electrolyte | Not easily precipitated | Coagulation takes place |
| Hydration | Extensive | No hydration |
| Examples | Gum, gelatin, starch, protein, rubber, etc. | Solutions of metal like Ag, Au, metal sulphides like $As_2S_3$ etc. |

- Depending upon the type of particles of dispersed phase.
  - **Multimolecular Colloids :** These solutions consist of aggregates of atoms or small molecules with diameter of less than 1 nm and these molecules held together with van der Waal's forces.

    *e.g.*, gold sols, sulphur ($S_8$) molecules
  - **Macromolecular Colloids :** In these colloids, the dispersed particles are themselves large molecules (usually polymers). Most lyophilic sols belong to this category.
  - **Micelles :** There are certain colloids which behave as normal strong electrolytes at low concentrations, but exhibit colloidal properties at higher concentration due to the formation of aggregated particles. These are known as **micelles** or **associated colloids**.

## PROPERTIES OF COLLOIDAL SOLUTION

### General Characteristics

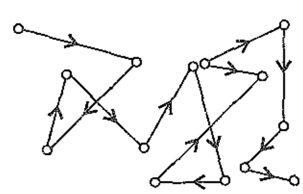
- **Visibility :** Colloidal particles are not visible with naked eye or with the help of microscope. Size and shape of colloidal particle is determined by:
  - Scanning electron microscope (SEM)
  - Transmission electron microscope (TEM)
  - Scanning transmission electron microscope (STEM)
- **Filterability :** The colloidal particles pass through an ordinary filter paper, but not through parchment or other fine membranes.
- **Heterogeneous character :** Colloidal solutions are heterogeneous as they consist of two phases (i) dispersed phase, and (ii) dispersion medium.

### Colligative Properties

- Due to formation of associated molecules, observed values of colligative properties like relative decrease in vapour pressure, elevation in boiling point, depression in freezing point, osmotic pressure are smaller than expected.

### Mechanical Properties

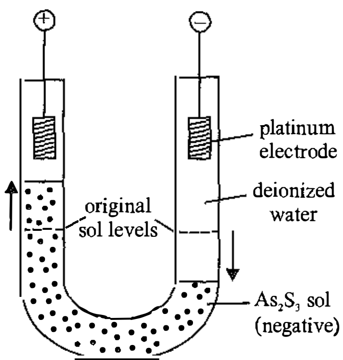
- **Brownian movement :** The molecules of the dispersion medium are constantly colliding with the particles of the dispersed phase, this causes a continuous zig-zag motion. This motion is known as **Brownian movement** after the name of its discoverer, Robert Brown.



  - Brownian motion is independent of the nature of colloid but depends on the size of the particles and viscosity of solution.
  - Smaller the size and lesser the viscosity, faster is the motion.
- **Sedimentation :** The colloidal particles settle down under the influence of gravity at a very low rate.

### Electrical Properties

- **Electrophoresis :** Colloidal particles possess some type of electric charge. Because of charge, colloidal particles move when electric field is applied. The phenomenon of movement of colloidal particles under an applied electric field is called electrophoresis.



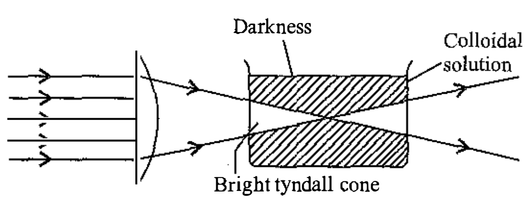

Electrophoresis is used to determine the charge on colloidal particles, if particle move towards negative electrode, the charge on the particle is positive and vice-versa.

- **Electro-osmosis :** The phenomenon of the movement of the molecules of the dispersion medium under the influence of electric field whereas colloidal particles are not allowed to move, is called electro-osmosis.

| Positively charged sols | Negatively charged sols |
|---|---|
| Hydrated metallic oxides. *e.g.*, $Al_2O_3 \cdot xH_2O$, $Fe_2O_3 \cdot xH_2O$, metal hydroxides, $Fe(OH)_3$, $Al(OH)_3$, basic dye stuff like Prussian blue, haemoglobin (blood). | Metallic particles. *e.g.*, Cu, Ag, Au Metal sulphides - *e.g.*, $As_2S_3$, CdS, Acidic dyes like eosin, congo red etc, sols of gelatin, gum, starch etc. |

### Optical Properties – Tyndall Effect

- The phenomenon of scattering of light by colloidal particles as a result of which the path of the beam becomes visible is called Tyndall effect. The illuminated path of the beam is called **Tyndall cone**.




  > Tyndall effect confirms the heterogeneous nature of colloidal solution.

- **Coagulation or flocculation :** The phenomenon of precipitation of a colloidal solution by the addition of an electrolyte is called **coagulation** or **flocculation**.
- The minimum concentration of an electrolyte required to cause coagulation of one litre of the colloidal sol is called its **flocculation value** and usually expressed in millimoles per litre.
- **Hardy-Schulze rule :** The greater the valency of the coagulating ion added, the greater is its power to cause coagulation.
- Flocculation value $\propto \dfrac{1}{\text{coagulating power}}$
- Number of mg of the dry protective colloid required to just prevent the coagulation of 10 mL of red gold sol when 1 mL of 10% solution of NaCl is added to it, is known as gold number.
- Protective power $\propto \dfrac{1}{\text{gold number}}$

**Illustration 1**

For the coagulation of 100 mL of arsenious sulphide solution, 5 mL of 1 M NaCl is required. What is the coagulating power of NaCl?

**Soln.:** Total volume after addition of 5 mL of 1 M NaCl solution = 105 mL.

Thus, 105 × molarity of NaCl in colloidal solution = 5 × 1

Molarity of NaCl in colloidal solution = $\dfrac{5}{105}$

Concentration in millimole = $\dfrac{5}{105} \times 1000 = 47.6$

**Illustration 2**

The coagulation of 100 mL of a colloidal solution of gold is completely prevented by adding 0.25 g of starch to it before adding 10 mL of 10% NaCl solution. Find out the gold number of starch.

**Soln.:** 10 mL of 10% NaCl solution is added to 100 mL of solution of gold.

Thus, 1 mL of 10% NaCl solution has been added to 10 mL solution of gold.

Since, 100 mL gold solution required = 0.25 g starch

$= 0.25 \times 10^3$ mg starch

So, 10 mL gold solution required $= \dfrac{0.25 \times 10^3}{100} \times 10$

= 25 mg starch

Thus, by definition, the gold number of starch is 25.

### EMULSIONS

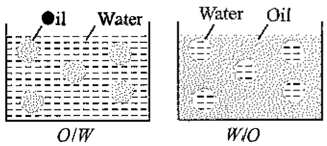
- Emulsions are colloidal systems in which dispersed phase as well as dispersion medium are normally liquids. The emulsions are generally unstable and form two separate layers on standing for sometimes. They can be stabilized by a third substance called emulsifiers. These agents reduce the interfacial tension between the two components forming the emulsion.

### Types of Emulsions

There are two types of emulsions :

- **Oil in water (*O/W*) type :** In this type, oil is dispersed phase and water is the dispersion medium. Milk is an emulsion of *O/W* type, where fat globules are dispersed in water.

- **Water in oil (*W/O*) type :** In this type, water is the dispersed phase and oil is the dispersion medium. Butter is an emulsion of *W/O* type.




### Emulsification

- The process of making an emulsion is known as **emulsification.** To stabilise an emulsion, small amount of third substance, which is known as emulsifying agent, is added. *e.g.*, soaps and detergents are emulsifier, they coat the drop of emulsion and check from coming together and make them stable. Other emulsifiers are proteins, gum and agar-agar.

### Demulsification

- Separation of an emulsion into its constituent liquids is called **demulsification**. Techniques applied for demulsification are freezing, boiling, centrifugation, electrostatic precipitation or chemical methods.

### Properties of Emulsion

- Emulsions exhibit all the properties like Tyndall effect, Brownian movement, electrophoresis, coagulation on addition of electrolytes as shown by colloidal sols.
- The size of the dispersed particles in emulsion is larger than those in the sols. It ranges from 1000Å to 10000Å.