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Colloidal State

A **colloid** is a heterogeneous system in which one substance is dispersed (dispersed phase) as very fine particles in another substance called dispersion medium. The study of the colloidal state of matter was started by **Thomas Graham** (1861).

Comparison of True Solution, Colloidal Solution and Suspension

	True solution	Colloidal solution	Suspension
(i)	Particle size < 10 Å (1 nm)	10 Å – 1000 Å (1 nm – 100 nm)	> 1000 Å (100 nm)
(ii)	Pass through filter paper as well as animal membrane.	Pass through filter paper but not through animal membrane.	Pass through neither of the two.
(iii)	Do not settle.	Do not settle.	Settle on standing.
(iv)	Particles are invisible.	Particles scatter light.	Particles are visible.
(v)	Diffuse quickly.	Diffuse slowly.	Do not diffuse.
(vi)	Clear and transparent.	Translucent.	Opaque.

Classification of Colloids

(A) Types of colloids based on physical state of dispersed phase and dispersion medium

Dispersed phase	Dispersion medium	Type of colloid	Examples
Solid	Solid	Solid sol	Coloured glasses and gem stones.
Solid	Liquid	Sol	Paints, cell fluids, ink, gold sol, proteins.
Solid	Gas	Aerosol	Smoke, dust
Liquid	Solid	Gel	Cheese, butter, jellies, boot polish.

Dispersed phase	Dispersion medium	Type of colloid	Examples
Liquid	Liquid	Emulsion	Milk, hair cream.
Liquid	Gas	Aerosol	Fog, mist, cloud, insecticide sprays.
Gas	Solid	Solid sol	Pumice stone, foam rubber.
Gas	Liquid	Foam	Froth, whipped cream, soap-suds.

Depending on the nature of dispersion medium, the colloids can be named as **hydrosols** or **aquasols** (for water), **alcosols** (for alcohols), **benzosols** (for benzene) and **aerosols** (for gases).

(B) Types of colloids based on nature of interaction between dispersed phase and dispersion medium

S. No.	Property	Lyophilic colloid	Lyophobic colloid
(i)	Formation	Formed easily by direct mixing the two phases.	Special chemical methods are required.
(ii)	Affinity for the medium	Have affinity for the dispersion medium.	Do not have any affinity for the dispersion medium.
(iii)	Stability	Highly stable due to the layers of dispersion medium.	Less stable and are easily coagulated due to the presence of charge.
(iv)	Reversibility	Reversible.	Irreversible.
(v)	Electrophoresis	May or may not show.	Show.
(vi)	Coagulation	Small amounts of electrolyte have no effect.	Small amounts of electrolyte may coagulate the sol.
(vii)	Examples	Sol of gum, gelatin, starch, rubber, etc.	Sol of metals and their sulphides.

(C) Types of colloids based on type of particles of the dispersed phase

Macromolecular colloids	Multimolecular colloids	Associated colloids
The colloids in which the dispersed phase particles are large molecules (usually polymer) having dimensions comparable to those of colloidal particles are called macromolecular colloids, e.g. starch, protein in water, synthetic rubber, polystyrene.	A colloid in which large number of atoms or smaller molecules of a substance aggregate together to form species having size in the colloidal range (1-1000 nm) is called multimolecular colloid, e.g. sulphur sol consists of particles containing a thousand or more of S_8 sulphur molecules.	These are the chemical substances which behave as normal strong electrolytes at low concentration but as colloids at higher concentration and are called micelles. Micelles may contain as many as 100 or more particles. These colloids have both lyophobic and lyophilic parts.

Kraft temperature (T_k) It is the minimum temperature of the colloidal system above which the formation of micelles takes place.

Critical micelle concentration (CMC) The minimum concentration of the surfactant at which the formation of a micelle takes place is called critical micelle concentration, e.g. CMC for soaps is ~ 10^{-4} to 10^{-3} mol L^{-1}.

Preparation of Colloids

Lyophilic sols can be easily prepared by shaking the lyophilic material with the dispersion medium, e.g. preparation of starch sol.

Lyophobic sols can be prepared by following methods.

Condensation/Aggregation Method

These methods involve the joining of a large number of small particles to form particles of colloidal size. Some methods are

(i) **Oxidation**

$$Br_2 + H_2S \longrightarrow 2HBr + \underset{\text{Colloidal sol}}{S}$$

$$SO_2 + 2H_2S \longrightarrow 3S(sol) + 2H_2O$$

(ii) **Reduction**

$$2AuCl_3 + 3SnCl_2 \longrightarrow \underset{\substack{\text{Gold sol or purple}\\ \text{of cassius}}}{2Au(sol)} + 3SnCl_4$$

(iii) **Hydrolysis**

$$FeCl_3 + 3H_2O \longrightarrow \underset{\text{Sol}}{Fe(OH)_3} + 3HCl$$

(iv) **Double decomposition**

$$As_2O_3 + 3H_2S \longrightarrow \underset{\text{Sol}}{As_2S_3} + 3H_2O$$

Dispersion/Disintegration Method

In this method, bigger particles are broken down to colloidal size. Some methods are

(i) **Mechanical disintegration** In this method, suspension is grind well in a colloid mill consisting of two steel discs which rotate in opposite directions at very high speed. The materials to be converted into colloidal sol is fed in between the two discs in the form of a wet slurry. The particles get broken to colloidal dimensions by the operating shearing force.

(ii) **Electrical disintegration/Bredig's Arc method** This process involves dispersion as well as condensation. In this method, electric arc is struck between electrodes of the metal (gold, silver, platinum, etc) immersed in the dispersion medium. The intense heat produced vapourises the metal which then condenses to form particles of colloidal size.

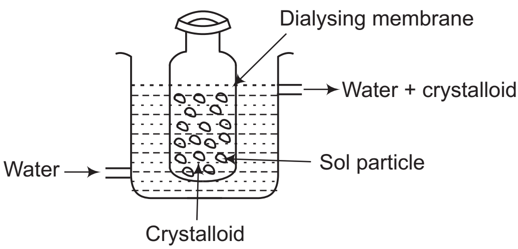
(iii) **Peptization** This method is used to convert fresh precipitate into colloidal state by shaking with dispersion medium in the presence of small amount of electrolyte. The electrolyte used (having an ion in common with the material to be dispersed) this purpose is called **peptizing agent**.

Purification of Colloidal Solutions

The process used for reducing the amount of impurities to a requisite minimum of a colloid, is known as purification of colloidal solutions.

(i) **Dialysis** It is based upon the principle that impurities of true solutions can pass through the parchment paper or cellophane membrane while, colloidal particles cannot.

In this process, dissolved substances are removed from the colloidal solution by means of diffusion through a suitable membrane.



(ii) **Electrodialysis** The process of dialysis is quite slow. So, if the dissolved substance in the impure colloidal solution is only the electrolyte, then electric field is applied. The colloidal solution is placed in a bag of suitable membrane, while pure water is taken outside.

(iii) **Ultrafiltration** Ultrafiltration is the process of separation of colloidal particles from the solvent and soluble solutes present in the colloidal solution by specially prepared filters, called ultrafilters.

Properties of Colloidal Solution

General Properties

(i) **Colligative property** Due to high average molecular masses of colloidal particles, mole fraction of the dispersed phase is very low. So, the values of colligative properties are very small.

(ii) **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 particles also depends on the manner in which the observer receives the light.

(iii) **Visibility** The particles of colloidal solution are not visible to naked eye or under ordinary microscope.

(iv) **Filterability** Colloidal particles can pass through ordinary filter paper, but can't pass through parchment paper or animal membrane.

Optical and Mechanical Properties

(i) **Brownian movement** Sol particles move in a random *zig-zag* manner due to the unequal impacts of the particles of dispersion medium on the particles of colloidal sol. It is called Brownian motion. Smaller the size of the particle and lesser the viscosity of the solution, faster is the motion.

(ii) **Tyndall effect** If a colloidal solution is placed in dark and a beam of light is passed through the sol, the path of light becomes visible with a bluish light. This phenomenon is called Tyndall effect. The scattering of light illuminates the path of beam in the colloidal dispersion.

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.

(ii) The refractive indices of the dispersed phase and the dispersion medium differ greatly in magnitude.

Tyndall effect is also observed when sunlight enters in a dark room through a slit or when light is thrown from a light projector in a cinema hall. Tale of comets is seen as a Tyndall cone due to scattering of light by the tiny solid particles, left by the comet in its path.

Electrical Properties

(i) **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 + ve or –ve. The charge on the particles is due to either of the given reasons:

(a) Due to preferential adsorption of either + ve or – ve ion which is common and present in excess, e.g. when $AgNO_3$ and KI solutions are mixed, the particles of AgI are precipitated. These particles can adsorb Ag^+ or I^- ions. If KI is in excess, I^- ions would be adsorbed giving [AgI] I^- negative sol but if $AgNO_3$ is in excess, a positive sol [AgI] Ag^+ is obtained.

SnO_2 can act as positively charged as well as negatively charged colloid depending upon the nature of medium.

(b) Due to electron capture by sol particles during electro dispersion method.

(c) By frictional electrification.

(d) By the dissociation of molecules followed by aggregation of ions. Two layers are developed on the particle, one is fixed layer and the other is diffused layer. Potential difference across this electric double layer is called **zeta potential** or **electrokinetic potential.**

Positively charged colloids are metal hydroxides, basic dyes like methylene blue sol, protein in acidic medium, oxides like TiO_2 sol. Examples of negatively charged colloids are metals (like Cu, Ag, Au, etc.), metal sulphide, acid dyes like eosin and sols of starch, gum, gelatin, clay, charcoal, etc.

(ii) **Electrophoresis** The phenomenon of movement of colloidal particles towards the oppositely charged electrodes under the influence of applied electric field is called electrophoresis.

(iii) **Coagulation/flocculation** The process of conversion of sol into a suspension is called flocculation or coagulation or precipitation.

It can be brought about by :

(a) addition of suitable electrolyte solution

(b) continuous electrophoresis

(c) prolonged dialysis

(d) mixing two oppositely charged colloidal solution

(e) heating or cooling

Coagulating value is the minimum amount of electrolyte (in millimoles/litres) needed to coagulate the colloidal solution. Smaller the coagulating or flocculating value of an electrolyte, greater is its coagulating power.

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

Hardy-Schulze rule Greater the valency of the oppositely charged ions of the electrolyte, more will be its coagulating power, *i.e.* coagulating power ∝ charge of ion, *e.g.* for As_2O_3 sol the order is, $Sn^{4+} > Al^{3+} > Ca^{2+} > Na^+$

Similarly for TiO_2 sol, the order is, $[Fe(CN)_6]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^-$

Protective Colloids

In the presence of a lyophilic colloid lyophobic sol gets protected towards the action of electrolyte. This phenomenon is called **protection** and the lyophilic colloid is termed as **protective colloid**.

Gold Number

The protective power of protective colloid is measured in terms of gold number which is defined as the number of mg of the protective colloid which just prevents the coagulation of 10 mL of standard gold sol when 1 mL of 10% solution of NaCl is added to it. Smaller the gold number of a protective colloid, greater is its protective power. Gold number of gelatin is 0.005-0.01 and of starch is 20-25.

Emulsion

It is a colloidal dispersion in which both dispersed phase and dispersion medium are liquid.

Types of Emulsions

(i) Oil in water [oil is dispersed phase and water is dispersion medium], e.g. milk.

(ii) Water in oil [water is dispersed phase and oil is dispersion medium], e.g. cod liver oil.

Dye test and dilution test must be used to distinguish between the two types of emulsions.

Characteristics of emulsion

Emulsions show all the properties of sols. Their important characteristics are as follows

(*i*) They can be diluted with liquid forming the dispersion medium in the emulsion.

(*ii*) Their particles size is larger than those of other size. It ranges from 1000 Å to 10 000 Å.

(*iii*) They scatter light and thus, exhibit Tyndall effect.

(*iv*) Brownian motion is also observed in emulsions where size of the particle is too near to the limit of 10^{-6}m.

Emulsifiers

Emulsifying agents or emulsifiers are the substances added in small quantity to stabilize the emulsions of fairly high concentration.

Demulsification The separation of an emulsion into its consituent liquids is called demulsification. It can be carried out by freezing, boiling, centrifugation, etc.

Gels

Gel is a liquid-solid colloidal system in which a liquid is dispersed in a solid. Gels are of two types : elastic gels (e.g. gelatin, agar-agar, starch) and non-elastic gels (e.g. silica, alumina and ferric oxide).

When gels are allowed to stand, they give out small quantity of trapped liquid and the gel shrinks in volume. This phenomenon is called **syneresis** or **weeping of gel**.

Colloids Around Us

Most of the substances we come across in our daily life are colloids. Following are the examples of colloids.

(i) Blue colour of the sky.

(ii) For, mist and rain.

(iii) Food articles like milk, butter, ice-creams, etc.

(iv) Blood which is a colloidal solution of an albuminoid substance.

(v) Fertile soils are colloidal in nature in which humus acts as a protective colloid.

(vi) Formation of delta.

Applications of Colloids

(i) In medicine, e.g. argyrol (a silver sol used as eye lotion).

(ii) In chrome tanning.

(iii) In sewage disposal.

(iv) In purification of drinking water.

(v) In the preparation of nano-materials often use as catalyst.

(vi) In photography.

(vii) In producing artificial rain.

(viii) Blood clotting by ferric chloride or potash alum.

(ix) In smoke precipitation (cottrell precipitator)