Colloidal Dispersions

Dispersed Systems

Dispersed systems consist of particulate matter, known as the dispersed phase, distributed throughout a continuous or dispersion medium. The dispersed material may range in size from particles of atomic and molecular dimensions to particles whose size is measured in millimeters.

Accordingly, a convenient means of classifying dispersed systems is on the basis of the mean particle diameter of the dispersed material.

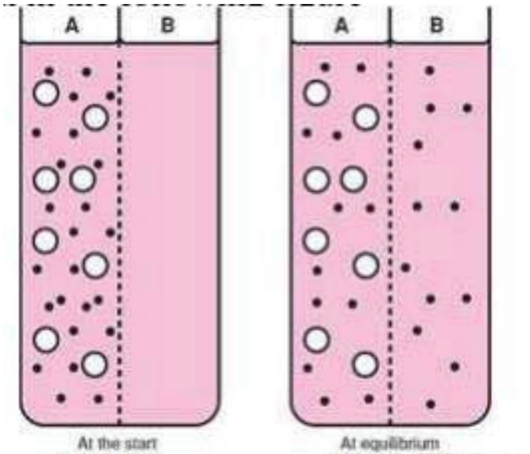
Based on the size of the dispersed phase, three types of dispersed systems are generally considered: (a) molecular dispersions, (b) colloidal dispersions, and (c) coarse dispersions. The size ranges assigned to these classes, together with some of the associated characteristics, are shown in the accompanying table

Classification of Dispersed Systems Based on Particle Size

Class	Particle Size*	Characteristics of System	Examples
Molecular dispersion	Less than 1 nm	1- Invisible in electron microscope 2- Pass through ultrafilter and semipermeable membrane 3- Undergo rapid diffusion	Oxygen molecules, ordinary ions, glucose
Colloidal dispersion	From 1 nm to 0.5 µm	1- Not resolved by ordinary microscope (although may be detected under ultramicroscope) Visible in electron microscope 2- Pass through filter paper 3- Do not pass semipermeable membrane 4- Diffuse very slowly	Colloidal silver sols, natural and synthetic polymers, cheese, butter, jelly, paint, milk, shaving cream, etc.
Coarse dispersion	Greater than 0.5 µm	1-Visible under microscope 2- Do not pass through normal filter paper 3-Do not pass through semipermeable membrane 4- Do not diffuse	Grains of sand, most pharmaceutical emulsions and suspensions, red blood cells
* 1 nm (nanometer) = 10^{-9} m; 1 µm (micrometer) = 10^{-6} m.			

Diffusion through a semipermeable membrane

Because the size of colloidal particles, they can be separated from molecular particles by the use of semipermeable membrane. This technique is known as **Dialysis.** As shown in the following figure



At start **At equilibrium**

Conditions on the two sides, A and B, of the membrane are shown at the start and at equilibrium. The open circles are the colloidal particles that are too large to pass through the membrane. The solid dots are the electrolyte particles that pass through the pores of the membrane.

Dialysis occurs in vivo. Thus, ions and small molecules pass readily from the blood, through a natural semipermeable membrane, to the tissue fluids; the colloidal components of the blood remain within the capillary system. The principle of dialysis is utilized in the artificial kidney, which removes low–molecular-weight impurities from the body by passage through a semipermeable membrane

Types of Colloidal Dispersions*
(According to the type of dispersed phase and dispersion medium)

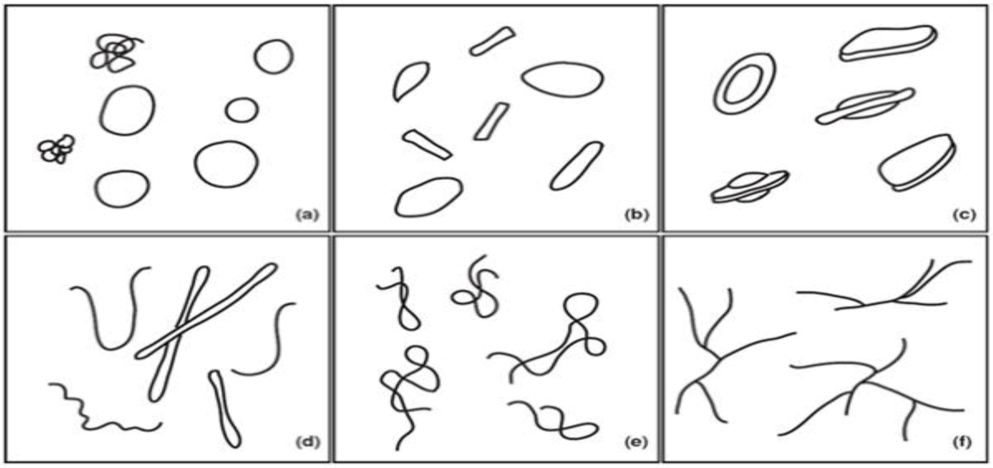
Dispersed Phase	Dispersion Medium	Colloid Type	Examples
Solid	Solid	Solid sol	Pearls, opals
Liquid	Solid	Solid emulsion	Cheese, butter
Gas	Solid	Solid foam	Pumice, marshmallow
Solid	Liquid	Sol, gel	Jelly, paint
Liquid	Liquid	Emulsion	Milk, mayonnaise
Gas	Liquid	Foam	Whipped cream, shaving cream
Solid	Gas	Solid aerosols	Smoke, dust
Liquid	Gas	Liquid aerosols	Clouds, mist, fog

Note :- a gas in gas always produce a solution

Types of Colloidal Dispersion
(According to the shape of dispersed particles)

The shape adopted by particles in dispersion is important because the more extended the particle, the greater is its specific surface and the greater is the opportunity for attractive forces to develop between the particles of the dispersed phase and the dispersion medium.

Some representative shapes of spherocolloids and fibrous colloids are shown in Figure below



Some shapes that can be assumed by colloidal particles: (a) spheres and globules, (b) short rods and prolate ellipsoids, (c) oblate ellipsoids and flakes, (d) long rods and threads, (e) loosely coiled threads, and (f) branched threads**.**

Types of Colloidal Systems

(According to the interaction between the dispersed phase and dispersion medium)

Lyophilic Colloids

Systems containing colloidal particles that interact to an appreciable extent with the dispersion medium are referred to as lyophilic (solvent-loving) colloids. Owing to their affinity for the dispersion medium, such materials form colloidal dispersions, or sols, with relative ease. Thus, lyophilic colloidal sols are usually obtained simply by dissolving the material in the solvent being used.

For example, the dissolution of acacia or gelatin in water leads to the formation of a sol.

The various properties of this class of colloids are due to the attraction between the dispersed phase and the dispersion medium, which leads to **solvation (** the attachment of solvent molecules to the molecules of the dispersed phase). In the case of hydrophilic colloids, in which water is the dispersion medium, this is term is known as hydration.

((One of the most important property of lyophilic colloid is the presence of solvent sheath))

Most lyophilic colloids are organic molecules, for example, gelatin, acacia, insulin, albumin, rubber, and polystyrene. Of these, the first four produce lyophilic colloids in aqueous dispersion media (hydrophilic sols). Rubber and polystyrene form lyophilic colloids in nonaqueous, organic solvents. These materials accordingly are referred to as lipophilic colloids.

These examples illustrate the important point that the term lyophilic has meaning only when applied to the material dispersed in a specific dispersion medium. **A material that forms a lyophilic colloidal system in one liquid (e.g., water) may not do so in another liquid (e.g., benzene).**

Lyophobic Colloids

The second class of colloids is composed of materials that have little attraction, if any, for the dispersion medium. These are the lyophobic (solvent-hating) colloids and, so, their properties differ from those of the lyophilic colloids. This is primarily due to the absence of a solvent sheath around the particle. Lyophobic colloids are generally composed of inorganic particles dispersed in water. Examples of such materials are gold, silver, sulfur, arsenous sulfide, and silver iodide.

In contrast to lyophilic colloids, it is necessary to use special methods to prepare lyophobic colloids.

Association Colloid

Association or amphiphilic colloids form the third group in this classification. They are certain organic molecules or ions, termed amphiphiles or surface-active agents, are characterized by having two distinct regions of opposing solution affinities within the same molecule or ion. When present in a liquid medium at low concentrations, the amphiphiles exist separately and are of such a size as to be subcolloidal. As the concentration is increased, aggregation occurs over a narrow concentration range. These aggregates, which may contain 50 or more monomers, are called micelles. **Because the diameter of each micelle is of the order of 50 Å, micelles lie within the size range of colloidal particles , such compounds are called association colloidal**.

Lyophilic	**Lyophobic**	**Association (Amphiphilic)**
Dispersed phase consists generally of large organic *molecules* lying within colloidal size range	Dispersed phase ordinarily consists of inorganic particles, such as gold or silver	Dispersed phase consists of aggregates (*micelles*) of small organic molecules or ions whose size *individually* is below the colloidal range
Molecules of dispersed phase are solvated, i.e., they are associated with the molecules comprising the dispersion medium	Little if any interaction occurs between particles and dispersion medium (no solvation)	Hydrophilic or lipophilic portion of the molecule is solvated, depending on whether the dispersion medium is aqueous or nonaqueous
Molecules disperse spontaneously to form colloidal solution	Material does not disperse spontaneously, and special procedures therefore must be adopted to produce colloidal dispersion	Colloidal aggregates are formed spontaneously when the concentration of amphiphile exceeds the critical micelle concentration
Viscosity of the dispersion medium ordinarily is increased greatly by the presence of the dispersed phase; at sufficiently high concentrations, the sol may become a gel; viscosity and gel formation are related to solvation effects and to the shape of the molecules, which are usually highly asymmetric	Viscosity of the dispersion medium is not greatly increased by the presence of lyophobic colloidal particles, which tend to be unsolvated and symmetric	Viscosity of the system increases as the concentration of the amphiphile increases, as micelles increase in number and become asymmetric
Dispersions are stable generally in the presence of electrolytes; they may be salted out by high concentrations of very soluble electrolytes; effect is due primarily to desolvation of lyophilic molecules	Lyophobic dispersions are unstable in the presence of even small concentrations of electrolytes; effect is due to neutralization of the charge on the particles; lyophilic colloids exert a protective effect	In aqueous solutions, the critical micelle concentration is reduced by the addition of electrolytes; salting out may occur at higher salt concentrations

Kinetic Properties of Colloids

There are several properties of colloidal systems that relate to the motion of particles with respect to the dispersion medium. The motion may be:-

1-Thermally induced
2- Gravitationally induced
3- Applied externally
4- Electrically induced motion

1-Thermally induced (increased by increasing temp)

Brownian motion

Brownian motion describes the random movement of colloidal particles. The erratic motion, resulting from the bombardment of the particles by the molecules of the dispersion medium. The motion of the molecules cannot be observed, of course, because the molecules are too small to see. The velocity of the particles increases with decreasing particle size, while increasing the viscosity of the medium decreases and finally stops the Brownian movement.

Diffusion

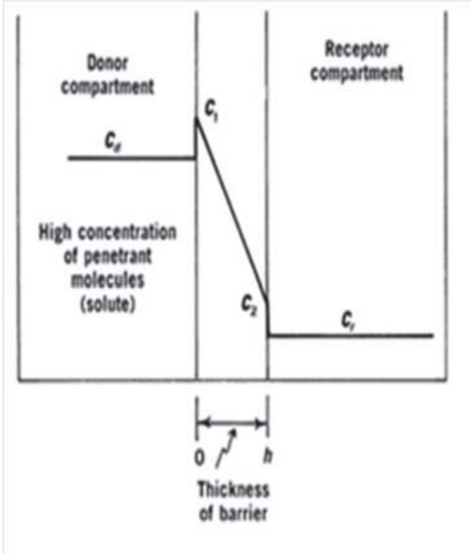
Particles diffuse spontaneously from a region of higher concentration to one of lower concentration until the concentration of the system is uniform throughout. Diffusion is a direct result of Brownian movement, therefore (all factors affect Brownian movement will affect diffusion)

According to **Fick's first law,** the amount (dq) of substance diffusing in time (dt) across a plane of area (S) is directly proportional to the change of concentration, dc, with distance traveled, dx.

Fick's law is written as

$$dq = - DS \frac{dc}{dx} dt$$

$$g = - D\ cm^2 \frac{g/cm\,3}{cm}\ sec \quad \rightarrow\rightarrow \quad D = cm^2 / sec.$$ **(Units)**



It is normal for the concentration curve to increase or decrease sharply at the boundaries of the barrier because, in general, C1 is different from Cd, and C2 is different from Cr

D is the diffusion coefficient, the amount of material diffusing per unit time across a unit area when dc/dx, called the concentration gradient, is unity.

D thus has the dimensions of area per unit time.

Negative sign in the equation, signifies that the diffusion occurs in decreasing concentration of diffusion

The passage of a substance may be through porous membrane or through tortuous pores or channels (example. Skin)

Smaller particles diffuse faster in a given media

Molecular > colloid > coarse

Passive diffusion caused by a concentration gradient and carried out through Brownian motion

It is important for the release of drug from topical preparation and in the GIT absorption of drugs

Osmosis

It is the action in which only the solvent is transferred, while the diffusion involve the passage of solute.

The osmotic pressure, π, of a dilute colloidal solution is described by the van't Hoff equation:

$\pi = cRT$

where c is molar concentration of solute , R, gas constant = 0.082 atm.mole/ L.deg

This equation can be used to calculate the molecular weight of a colloid in a dilute solution.

2- Gravitationally induced

Sedimentation

The velocity, v, of sedimentation of spherical particles having a density ρ in a dispersion medium of density ρ_0 and a viscosity η_0 is given by **Stokes's law**:

$$V = \frac{2r^2(\rho - \rho_0)\,g}{9\,\eta 0}$$

r = radius of particle, ρ = density of particle, ρ_0 = density of the dispersion medium

η_0 = viscosity of the dispersion medium, g = is the acceleration due to gravity

Factors affecting sedimentation

- Particle size (↓ particle size → ↓ sedimentation)
- Viscosity (↑ viscosity → ↓ sedimentation)
- Difference between the densities of the dispersed particles and the dispersion medium (↑ difference → ↑ sedimentation)

If the particles are subjected only to the force of gravity, then the lower size limit of particles obeying Stokes's equation is about 0.5 μm. This is because Brownian movement becomes significant and tends to offset sedimentation due to gravity and promotes mixing instead.

Consequently, a stronger force must be applied to bring about the sedimentation of colloidal particles in a quantitative and measurable manner. This is accomplished by use of the ultracentrifuge, which can produce a force one million times that of gravity.

3- Applied externally

Viscosity

Viscosity is an expression of the resistance to flow of a system under an applied stress. The more viscous a liquid is, the greater is the applied force required to make it flow at a particular rate.

Viscosity study can give us information about

- The shape of particles in dispersion
- The molecular weight of the dispersed phase

The shape of particles in dispersion

The shapes of particles of the disperse phase affect the viscosity of colloidal dispersions. Spherocolloids form dispersions of relatively low viscosity, whereas systems containing linear particles are more viscous. The relationship of shape and viscosity reflects the degree of solvation of the particles. If a linear colloid is placed in a solvent for which it has a low affinity, it tends to "ball up," that is, to assume a spherical shape, and the viscosity falls. This provides a means of detecting changes in the shape of flexible colloidal particles and macromolecules.

The molecular weight of the dispersed phase

The molecular weight of the is measured by using viscometer and the molecular weight obtained by this technique is called viscosity average molecular weight .

The molecular weight of the polymer solution is very high so the viscosity of polymer solution is very high compared to that of pure solvent.

From the Mark-Houwink equation the relationship between the molecular weight and viscosity is given below

$$[\eta] = KM^{\alpha}$$

Where $[\eta]$ is the intrinsic viscosity, M is the molecular weight, K and α are constants for a particular polymer solvent system.

If we know the k and α values for a given polymer solution, the intrinsic viscosity and molecular weight can be calculated using the above equation.

4- Electrically induced motion

It is the movement of charged surface with respect to an adjacent liquid phase. One of the most important application for such movement is the electrophoresis.