COLLOID and SURFACE SCIENCE

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Colloid Science

- *Colloid science concerns systems in which one or more of the components has at least one dimension within the nanometre (10^{-9} m) to micrometre (10^{-6} m) range.*
- *True Solution species < 10^{-9} m*
- *Suspensions particles > 10^{-6} m*

Definition of Colloid

- *Any particle that has some linear dimension between (10^{-9} m) and (10^{-6} m) is considered as colloid.*
- *i.e. Linear dimensions rather than particle weight or the number of atoms in a particle will define the colloidal size rang.*
- *Smaller particles ($< 10^{-9}$ m) considered with other branches of chemistry.*
- *Larger particles ($> 10^{-6}$ m) considered with other sciences of chemistry. rue Solution species $< 10^{-9}$ m*

Surface and Interface

- *Colloid and interface meet in the systems of more than one phase.*
- *The word " Surface" is used in the chemical sense of phase boundary rather than in a geometrical sense.*
- *i.e. It is the region in which the properties vary from those of one phase to those of the adjoining phase.*
- *This transition occurs over distance of molecular dimensions at least .*
- *Thus, the surface has thickness.*

Surface and Interface

- *The term "interface" simply highlight the fact that the surface of interest is the dividing region between two phases.*

- Surface = interface, and Interface = Surface.
- But
- Surface: Specially used for (gas-liq, gas-solid) systems.
- Interface: Specially (liq-liq, solid-solid, and liq-solid) systems.

Comparison of Solutions, Colloids, and Suspensions

Type of Mixture	Type of Particle	Effect of Light	Settling	Separation
Solution	Small particles such as single atoms, ions, or molecules	Transparent	Particles do not settle	Particles cannot be separated by filters or semipermeable membranes
Colloid	Larger molecules or groups of molecules or ions	Tyndall effect	Particles do not settle	Particles can be separated by semipermeable membranes
Suspension	Very large particles that may be visible	Opaque	Particles settle rapidly	Particles can be separated by filters

Examples of systems which are colloidal

- ***aerosols**, **agrochemicals**, **cement**, **cosmetics**, **dyestuffs**, **emulsions**, **fabrics**, **foams**, **foodstuffs**, **ink**, **paint**, **paper**, **pharmaceuticals**, **plastics**, **rubber**, **and soil**.*

Examples of processes, which rely on the application of colloidal phenomena are:

- ***adhesion, ore flotation chromatography, precipitation, detergency, road surfacing, electrophoretic deposition, emulsion, polymerisation, food processing, grinding, heterogeneous catalysis, ion exchange, lubrication, oil–well drilling, soil conditioning, sugar refining, water clarification, water evaporation control, water repellency, and wetting***

Examples of Disciplines and Topics in which Colloidal Phenomena are Important

Discipline	Example
Analyticla Chemistry	Ads indicators, ion exchange, chromatography
Physical Chemistry	Nucleation, supercooling, liquid crystals
Molecular biology	Electrophoresis, osmotic, Donnan equilibrium.
Material Science	Powders, ceramics, plastics

Examples of Disciplines and Topics in which Colloidal Phenomena are Important

Discipline	Example
Environmental science	Aerosols, fog, foam, water purification.
Petroleum and Geology	Oil recovery, ore enrichment, soil porosity
House hold and consumer products	Milk, waterproofing, cosmetic materials
Imaging technology	Photographic emulsions, xerography, printing, slim flat screens.

Facts About Surface and Interface

- **1. Increase in Surface and Energy with Decrease in Size.**

Cut No	R (cm)	No.	Area (cm^2)
1	1	1	12.6
1	0.5	8	25.1
2	0.25	64	50.3
3	0.125	512	101

Facts

- **2. The existence of matter in the colloidal state may be:**
  - ***desirable, or***
  - ***undesirable.***

- **Therefore, it is important to know both:**
  - ***how to make, and***
  - ***how to destroy colloidal systems.***

Facts

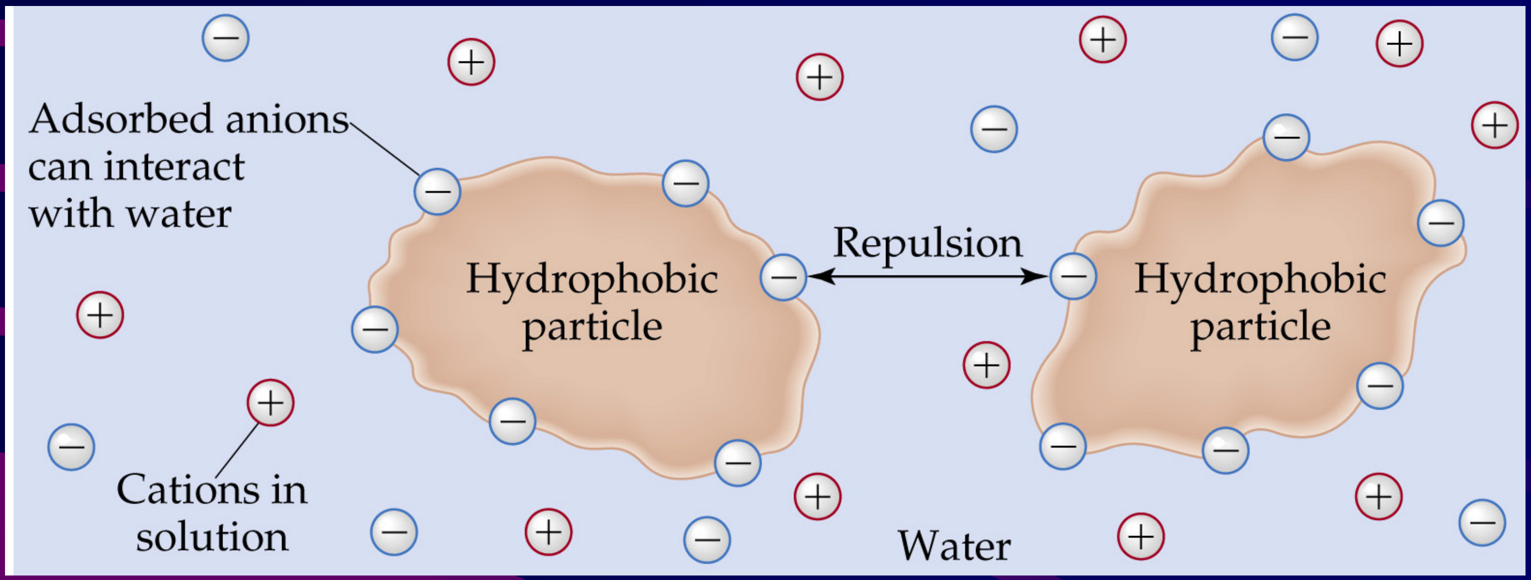
- **3. Colloid science is an interdisciplinary subject.**
- **4. Colloid science can be understood at both descriptive and theoretical levels.**
- **5. The factors which contribute most to the overall nature of a colloidal system are:**
  - **Particle size.**
  - **Particle shape and flexibility**
  - **Surface (including electrical) properties**
  - **Particle-particle interactions**
  - **Particle-solvent interactions**

General Classification of Colloidal Systems

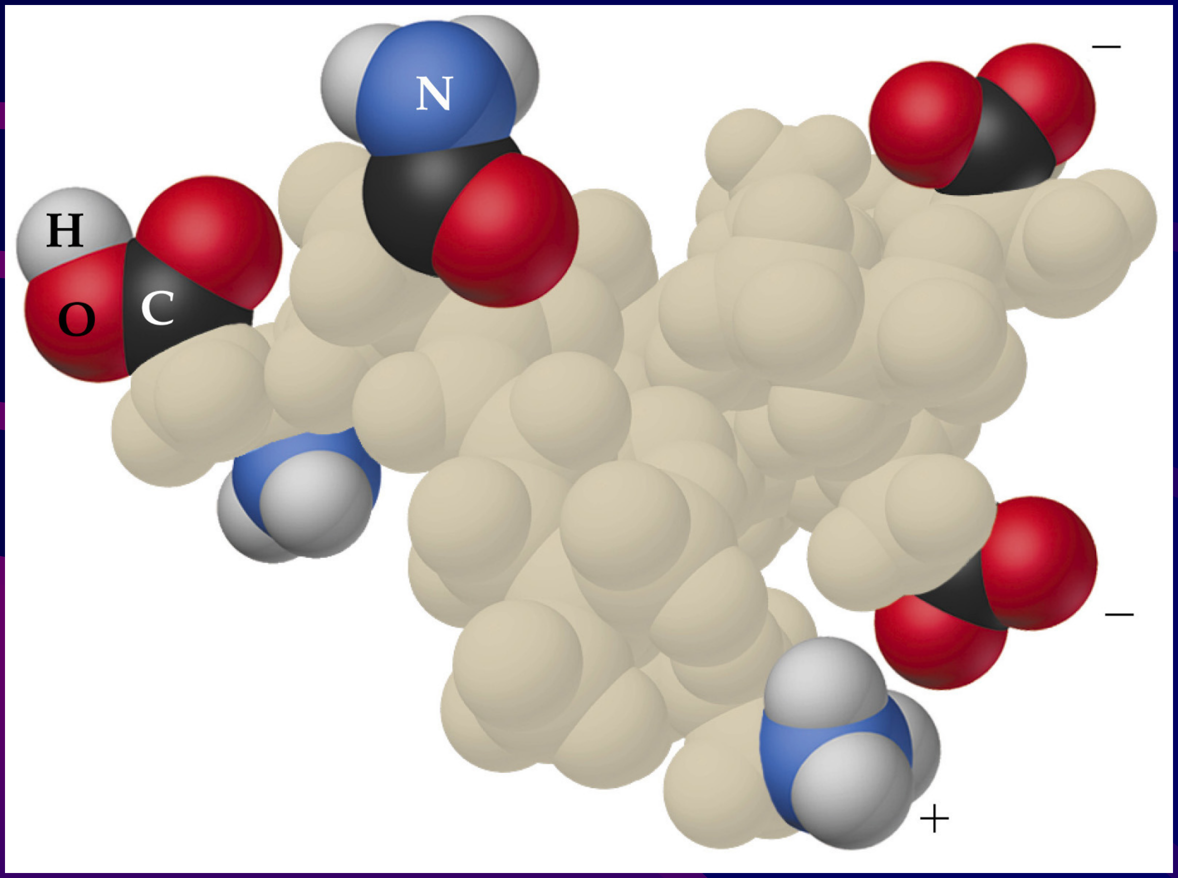
- *I. Colloidal Dispersions: thermodynamically unstable and irreversible system, why?*
- **II. True solutions of macromolecules,** ***thermo–dynamically stable and reversible.***
- **III. Association colloids, thermodynamically stable.**

Dispersion Colloids

Hydrophobic Particles

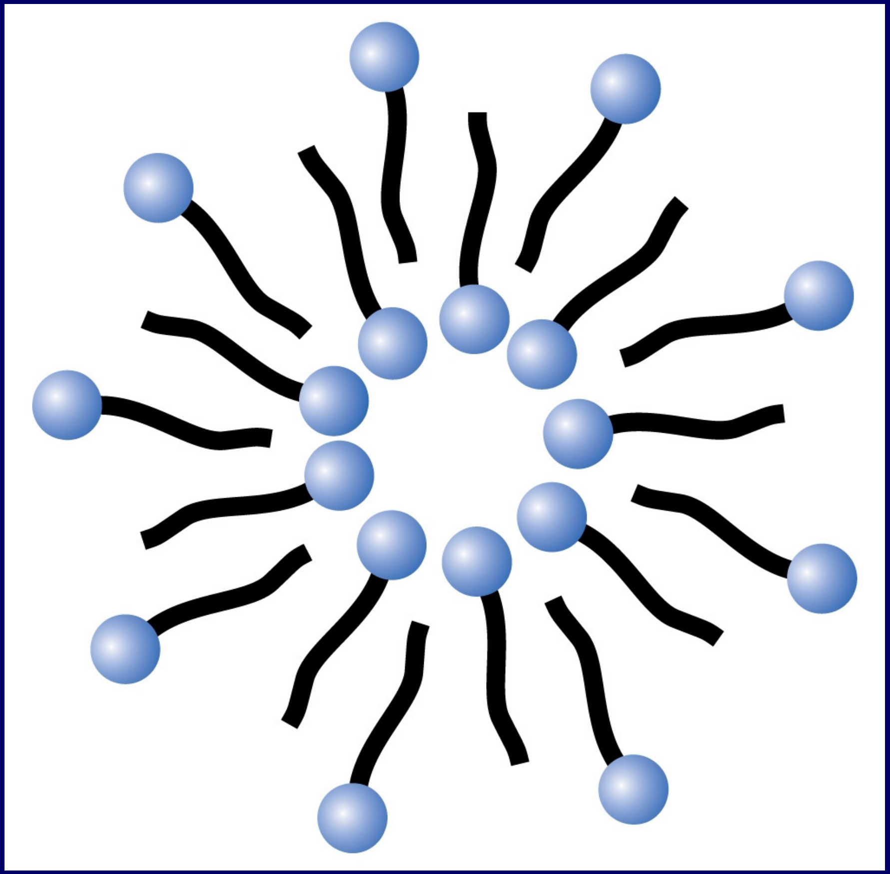


Macromolecule colloids



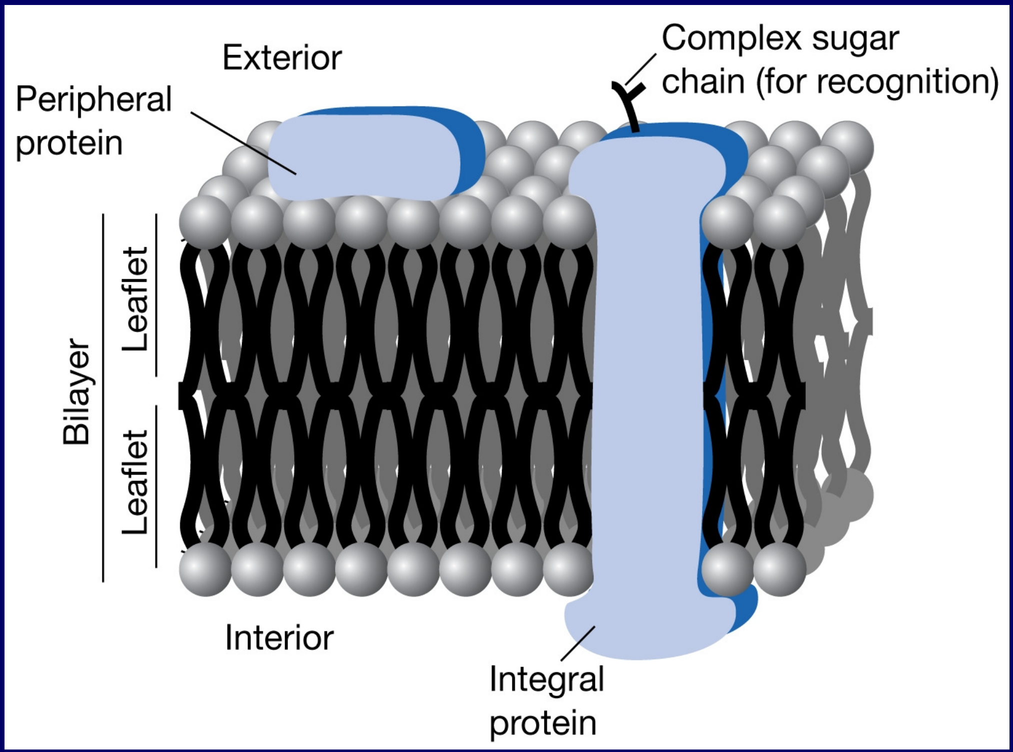
Association colloids - micelle formation

Bilayer Structure of micelles



Association colloids - micelle formation

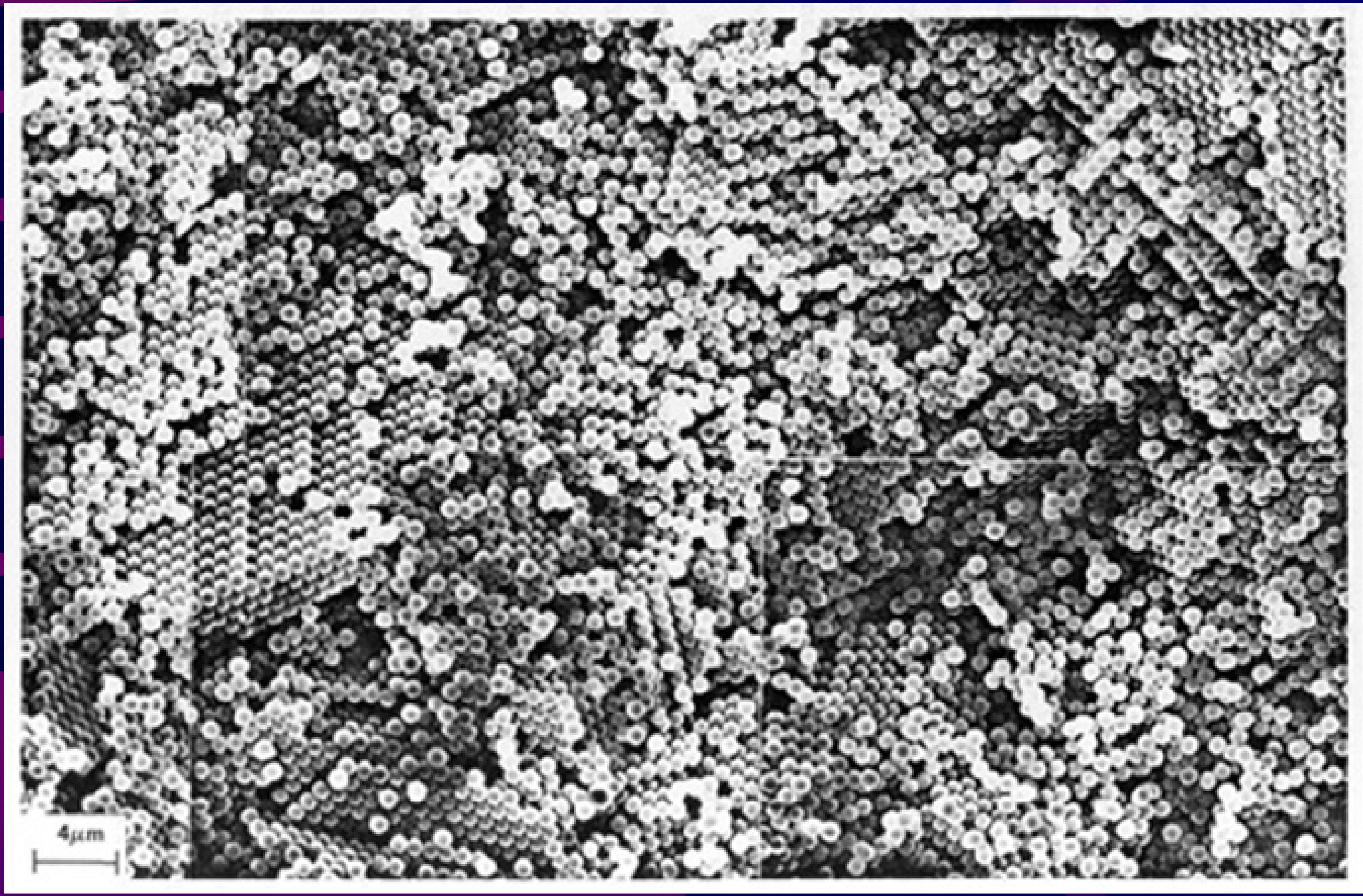
Lamellar Structure of micelles



Dispersions

Dispersions

- Simple colloidal dispersions are, two–phase systems distinguished by the terms dispersed phase and dispersion medium.
- The most important types of colloidal dispersion are
  - Sols (solid or liquid in liquid)
  - emulsions (liquid in liquid)
  - Foams (gas in liquid).



Colloidal Size particles

Types of colloidal dispersion

Dispersed phase	Dispersion medium	Name	Examples
Liquid	Gas	Liquid aerosol	Fog, liquid sprays
Solid	Gas	Solid aerosol	Smoke, dust
Gas	Liquid	Foam	Foam, fire extinguisher
Liquid	Liquid	Emulsion	Milk, Mayonnaise

Types of colloidal dispersion

Dispersed phase	Dispersion medium	Name	Examples
Solid	Liquid	Sol, Paste (high solid conc.)	Au sol, AgI sol Toothpaste
Gas	Solid	Solid foam	Extended polystyrene
Liquid	Solid	Solid emulsion	Opal, pearl
Solid	Solid	Solid suspension	Pigmented plastics

Classification of Colloids Based on Affinity to the Dispersion Medium

- ***Lyophilic*:: *liquid–loving***
- ***Lyophobic liquid–hating***

- These terms used to describe the tendency of a surfsce or functional group to become wetted or solvated.
- When the liquid medium is aqueous, the terms are::

  Hydrophilic, and Hydrophobic
- Lyophilic surface can be made Lyophobic and vice versa, Give Examples?

1.2
Structural characteristics of colloids

A. Experimental methods

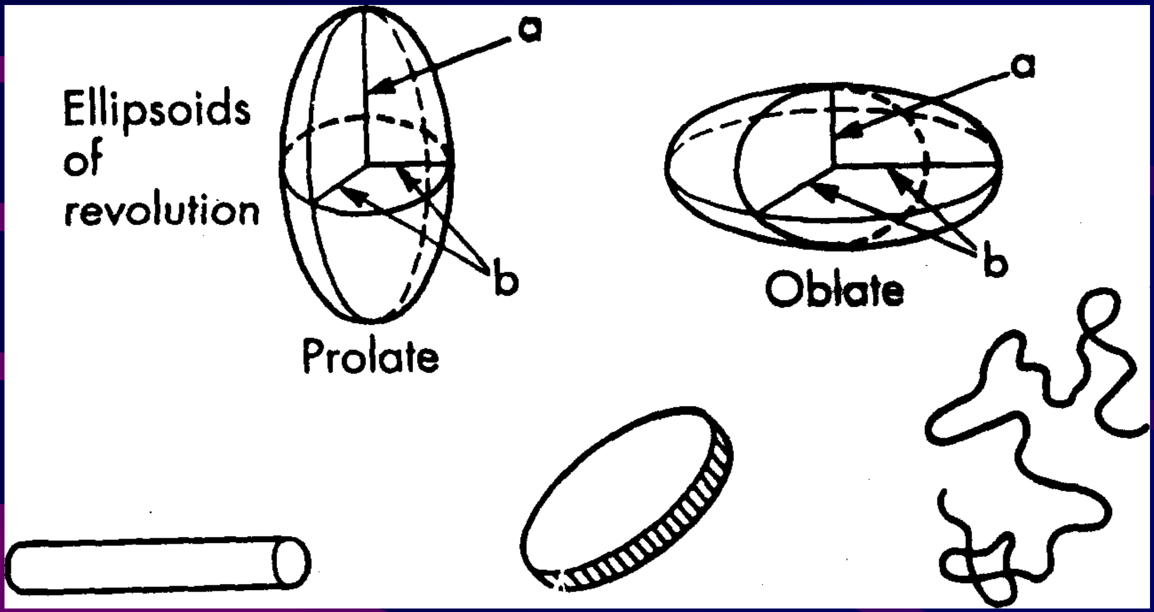
- The experimental procedures for determining particle size and shape can roughly be categorized, as follows:

1. Observation of the movement of particles in response to an applied force,
2. Direct observation of particle images SEM and TEM
3. Observation of the response of particles to electromagnetic radiation.
4. Measurements which relate to the total surface area of the particles (gas adsorption and adsorption from solution)

B. Particle shape

- **Particle asymmetry is a factor in determining the overall properties (especially mechanical) of colloidal systems.**
- **Colloidal particles can be classified according to shape as *corpuscular*, *laminar* or *linear*.**
- **The exact shape may be complex but, to a first approximation, the particles can often be treated theoretically in terms of models, which have relatively simple shapes (Figure 1.1).**

B. Particle shape



Rod *Disc* **Random coil**

Figure 1.1 Some model representations for non-spherical particles

1. The Spherical Model

- The easiest model to treat theoretically is the sphere (many colloidal systems contain spherical or nearly spherical particles).
- Emulsions, latexes, liquid aerosols, etc., contain spherical particles.
- Certain protein molecules are approximately spherical.
- The crystallite particles in dispersions such as gold and silver iodide sols are sufficiency symmetrical to behave like spheres.

2. Corpuscular Shape

- Corpuscular particles which deviate from spherical shape can often be treated theoretically as ellipsoids of revolution. Many proteins approximate this shape.
- An ellipsoid of revolution is characterized by its axial ratio, which is the ratio of the single half-axis *a* to the radius of revolution *b. i.e ratio a/b*
  - The axial ratio $a/b > 1$ for a prolate, and
  - $a/b < 1$ for an oblate (discus-shaped) ellipsoid.
- Iron(III) oxide and clay suspensions are examples of systems containing plate-like particles.

3. Thread-like Shape

- High-polymeric material usually exists in the form of long thread-like straight or branched-chain molecules. As a result of inter-chain attraction or cross-linking (arising from covalent bonding, hydrogen bonding or van der Waals forces) and entanglement of the polymer chains, these materials often exhibit considerable mechanical strength and durability. This is not possible when the particles are corpuscular or laminar..

Remarks

- In nature, thread-like polymeric material fulfils an essential structural role.
  - Plant life is built mainly from cellulose fibers.
  - Animal life is built from linear protein material such as collagen in skin, sinew and bone, keratin in nails and hair.

- Finally, When particles aggregate together, many different

  shapes can be formed. These do not necessarily correspond to the shape of the primary particles.

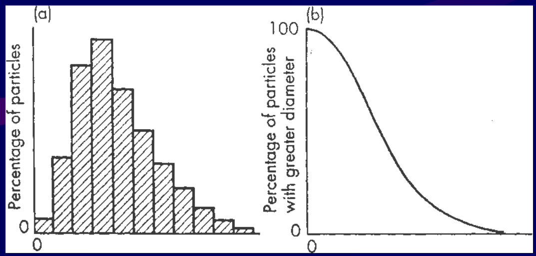
3. Flexibility

- *Thread-like like-polymer molecules show considerable flexibility due to rotation about carbon-carbon and other bonds.*
- *A better theoretical treatment is to consider the polymer molecules as random coils (even this model is not completely accurate).*
- *The relative magnitudes of polymer-polymer and polymer-solvent forces must also be taken into account.*
  - *If the segments of the polymer chain tend to stick ro one another, then a tighter than random coil, and possibly precipitation, will result;*
  - *whereas a looser coil results when the polymer segments tend to avoid one another because of strong solvation and/or electrical repulsion,*

4. Solvation

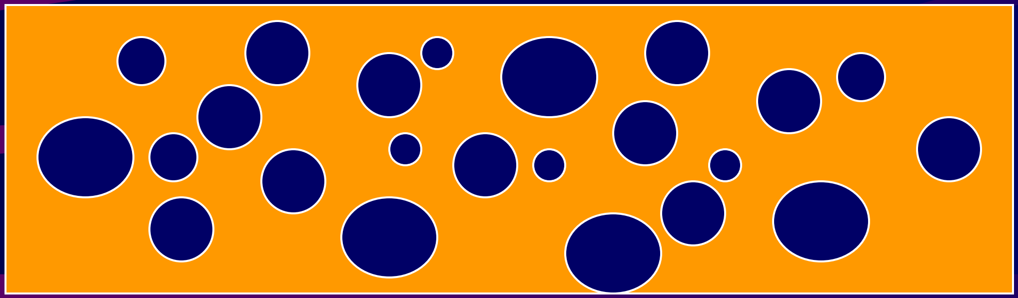
- **Colloidal particles are usually solvated, often to *the* extent of about one molecular layer, *and* this tightly bound solvent must be treated as a part of the particle.**
- **Sometimes much greater amounts of solvent can be immobilized by mechanical entrapment within particle aggregates.**
- **In solutions of long thread-like molecules the polymer chains may cross-link, and/or become mechanically entangled so that a continuous Three-dimensional network is formed.**
- **If all of the solvent becomes mechanically trapped and immobilized within this network, the system as a whole takes on a solid appearance and is called**

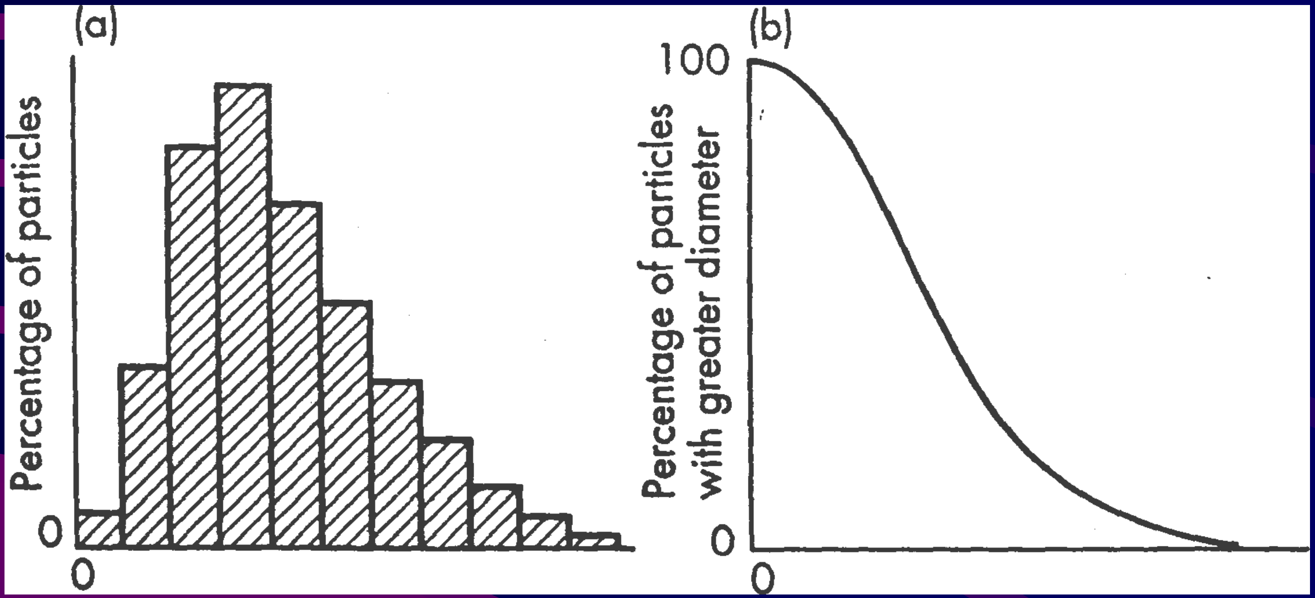
5. Polydispersed **nature**



- ***Colloidal systems are generally of a poly-dispersed nature - i.e. the molecules or particles in a particular sample vary in size, Why? Answer: By virtue of their stepwise build-up,***
- ***Colloidal particle and polymer molecular sizes tend to have skew distributions, as illustrated in Figure 1,2, for which [lie Poisson distribution].***
- ***Very often, detailed determination of relative molecular mass or particle size distribution is impracticable.***
- ***The significance of the word average: depends on the property which being measured. Therefore two values may be obtained:***
  - ***Number Average, and***
  - ***Mass Average.***

Particle Size Polydispersed





Particle diameter distribution for a polydispersed colloidal dispersion expressed (a) in histogram form, and (b) as a cumulative distribution **1.2**

Number Average and *Mass Average*

- *Osmotic pressure, which is a colligative property, depends on the number of solute molecules present yields a number-average relative molecular mass M_r ,i.e. number of molecules of relative molecular mass*

$$Mr = \frac{\sum n_i M_{r,i}}{\sum n_i}$$

- *If the contribution of each particle is proportional to its mass (as in), a mass-average relative molecular mass M_r or particle mass is given.*

$$Mr = \frac{\sum n_i M_{r,i}^2}{\sum n_i M_{r,i}}$$