→ Colloidal state:→

→ Introduction:→

- Thomas Graham classified substances on the basis of diffusion of various substances in a liquid medium.
  (i) Crytalloids:- They diffuse rapidly in solution and can rapidly pass through animal or vegetable membrane. e.g. Urea, sugar, salt and other crystalline substances.
  (ii) Colloids:→ They diffuse very slowly in solution and cannot pass through animal or vegetable membranes. e.g. starch, gelatin, silicic acid, proteins etc.
  This class of substances generally exist in amorphous or gelatinous condition, and hence the name "colloid" meaning "glue form".
- In recent years, it has been observed that every substance irrespective of its nature can be a crystalloid or colloid under suitable conditions. For example.
  (i) NaCl is crystalloid in water but behaves like colloid in benzene.
  (ii) Soap is a colloid in water, while it behaves like crystalloid in benzene.

From the above examples, it is clear that the concepts of crystalloid and colloids do not hold good. Thus, colloidal state may be defined as-

"A substance is said to be in colloidal state, when it is dispersed in another medium in the form of very small particles having diameter between 10^{-5} to 10^{-7} cm."

- Molecular size in true solution → 10^{-7} to 10^{-8} cm
- Colloidal particle size → 10^{-5} to 10^{-7} cm
- Coarse suspension particle size → 10^{-3} to 10^{-5} cm

→ True solutions, colloidal solutions and suspensions: →

Characteristic property	Suspensions	Colloidal solutions	True solutions
1. Nature	Heterogeneous	Heterogeneous	Homogeneous
2. Particle size	Greater than 10^{-5} cm or 0·1μ or 100 mμ in diameter.	In between 10^{-7} to 10^{-5} cm or 1 mμ to 0·1μ in diameter.	Less than 10^{-7} cm or 1 mμ in diameter.
3. Diffusibility	They do not diffuse.	They diffuse slowly.	They diffuse rapidly.
4. Filtration	They can be filtered even by using an ordinary filter-paper.	They can be filtered through an animal membrane through which no colloidal particles pass.	They cannot be filtered.
5. Visibility	Their particles are visible under a microscope or even with a naked eye.	Their particles are only visible under ultramicroscope	Their particles are not visible even under ultra-microscope.
6. Setting	Their particles settle under gravity.	Their particles settle only in a centrifuge.	Their particles do not settle clear.
7. Appearance	Opaque.	Generally clear	Clear

8.	Molecular weight	Low	High	Low
9.	Osmotic pressure	High	Low	High
	O.P. $\propto \frac{1}{M.W.}$			
10.	Colour	They do not have definite colour.	Their colour depends upon the shape and size of the particles.	Their colour depends upon the ions present.
11.	Tyndall effect	They do not exhibit.	They do exhibit.	They do not exhibit.
12.	Brownian moment	—do—	—do—	—do—
13.	Electro-phoresis	—do—	—do—	—do—
14.	Coagulation	They are not coagulated.	They can be coagulated by adding suitable electro-lytes.	They can be precipitated by adding suitable electrolytes.
15.	Presence of electric charge		The particles carry either +ve or —ve charge	The particles do not carry any charge.

→ Classification of Colloids :→

– There are a number of basis for the classification of colloids.

1. Depending upon the nature of the dispersed phase and dispersion medium.

S. No.	Dispersed phase	Dispersion medium	Name	Examples
1.	Solid	Solid	Solid sol	Coloured glass, gems, alloys.
2.	Solid	Liquid	Sol	Paints, inks, white of eggs, mud.
3.	Solid	Gas	Aerosol	Smoke, dust.
4.	Liquid	Solid	Gel	Curds, pudding, cheese, jellies.
5.	Liquid	Liquid	Emulsion	Milk, cream, butter, oil in water.
6.	Liquid	Gas	Liquid aerosol	Clouds, mist, fog (water in air).
7.	Gas	Solid	Solid foam	Cake, bread, lava, pumice stone.
8.	Gas	Liquid	Foam	Soap lather, froth on beer, whipped cream.

* Since two gases are completely miscible with each other, they always form a true solution.

2. Depending upon the appearance of colloids :→

(a) Sol :- When a colloidal solution appears as fluid, it is termed as sol.

- Sols are named on the basis of dispersion medium.

dispersion medium → Water ; hydrosols.
dispersion medium → Alcohol ; alcosols.

(b) Gels :- When a colloid has a solid like appearance, it is termed as sol.

- The rigidity of gel varies from substance to substance.
- Some substances may occur both as sols as well as gels. This depends upon the relative concentrations of the dispersed phase and the dispersion medium.

3. Depending upon the interaction of two phases :→

- This classification was suggested by Perrin and Freundlich.

(a) Lyophobic or solvent-hating :→

- When the dispersed phase has less affinity for the dispersion medium, the colloids are termed as lyophobic.
- When the dispersion medium is water, they are called hydrophobic.
  e.g. Metals, NaCl etc.

(b) Lyophilic or solvent-loving :→

- When dispered phase has a greater affinity for dispersion medium, the colloids are termed as lyophilic.
- When the dispersed medium is water, they are called hydrophilic.

- They are also called natural colloids.
  e.g. starch, proteins, rubber etc.
- The lyophilic colloids are also called suspensoids when they are present a fluid apperance and are not stable.
- Most inorganic colloids are hydrophobic and most organic are lyophilic.

4. Depending upon the electrical charge on the dispersed phase :→

(a) Positive colloids :→ The dispersed phase carried +ve charge.
e.g. $Fe(OH)_3$ sol in water, methylene blue sol, TiO_2 sol etc.

(b) Negative colloids :→ The dispersed phase carried -ve charge.
e.g. As_3S_3 sol in water, copper sol, gold sol, eosin sol, congo red sol etc.

5. Depending upon the structure of colloid particles :→

- This classification was suggested by Lumiere and others.

(a) Molecular colloids :→ The particles of these colloids are single macromolecules and their structure is similar to that of small molecules.
e.g. Albumin, silicon, rubber, etc.

(b) Micellar colloids :→ The particles of these colloids are aggregates of many molecules or groups of atoms which are held together by cohesive or van der Waal's forces.
e.g. sulphur, gold, soap, detergents etc.

6. Based on particle size:→

(a) Sphero colloids:→ composed of globular particles.
e.g. albumin

(b) Linear colloids:→ composed of fibrous units.
e.g. denaturated albumin.

7. Based on chemical composition:→

(a) Inorganic colloids :→ Ag sol, Au sol, graphite, sulphur, $Fe(OH)_3$ sol, TiO_2 sol etc.

(b) Organic colloids:→ Rubber in benzene (homopolar sol), starch (hydroxy sol), Protein, soap in water (Heteropolar sol)

→ Solid in liquids (sols):→

- Sols are solid-liquid colloidal system, i.e., the dispersed phase is solid and dispersion medium is liquid.

→ Preparation of sols:→

- The primary consideration in the preparation of colloidal solution is that the dispersed particles should be within the range of 1 mμ - 200 mμ.
- The lyophilic sols can be readily prepared since colloidal materials such as starch, gelatin etc. when added to water swell up and spontaneously break into particulates of matter of colloidal range.
- The lyophobic sols, however, require special technique for their preparation. The methods consist in 1. Breaking down the coarser aggregates into particles of colloidal size.
  2. Grouping molecules into larger aggregates of colloidal size.

The methods belonging to these two categories are known as dispersion and condensation methods, respectively.

A. Dispersion Methods:→

1. Mechanical dispersion:→

- In this method, breaking down of the solid coarser/solid particles is done by mechanical grinding.
- Mechanical grinding is done by "colloid mill" which consist of two metal discs held at a very small distance apart from one another which are reloving at a high speed (7000 rpm) in opposite direction.

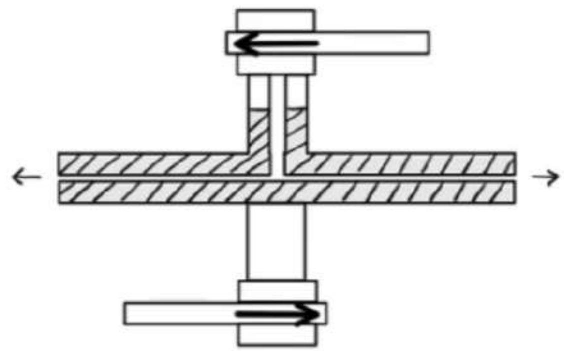


Fig:- Colloid Mill

- The material to be ground is fed in between the two discs in the form of wet slurry.
- The particles get broken to colloidal dimentions by the operating shearing force.
- Some sols can alternatively be prepared by mechanical dispersion in a high intensity ultrasonic generators operating at a frequency of 20 KHz and above. Ultrasonic vibration are obtained by piezoelectric oscillations which convert electric vibrations of high frequency into mechanical vibrations.

This techniqe is used for soft substances such as sulphur, graphite, resins and gypsum.

2. Electrical dispersion: (Bredig's arc method):→

- This method was introduced by G. Bredig in 1908.
- In this method, metal first changes into vapours (molecular state) on account of the heat of the spark and the vapours then condense in water to give aggregates of colloidal range.
- In this method, an arc is struck between the two electrods of metal Pt, Au, Ag or Cu, in water containing traces of alkali.
- T. Svedberg introduced a method to obtain organosols of metals and non-metals. In this method, the electrodes are usually of Fe or Al and alternating current (Bredig's used direct current) is employed.

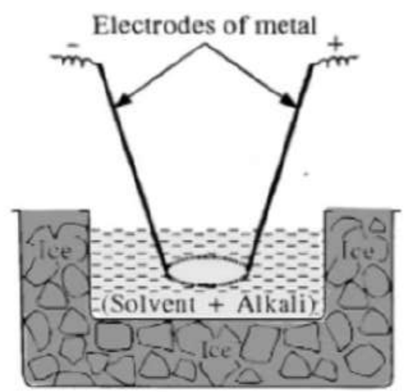


Fig. Bredig's arc method

The materials to be dispersed is taken in the form of granules and pasted on the electrodes through which electric arc is passed.

Organosols are used as catalyst, as fillers of plastic, glues, anticorrosive paints and in medicines.

3. Peptization:→

- The process of bringing a precipited substance back into the colloids state is known as peptization.
- It is carried out by the addition of an electrolyte. The electrolyte added is termed as peptising or dispersing agent.
- Peptization involves the adsorption of a suitable ion supplied by the electrolyte added by the particles of the precipitate. The particles aquire a positive or negative charge depending upon the charge on the ion absorbed. Because of the presence of same type of charge, the particles of the precipitate are pushed apart. The precipitate thus gets dispersed resulting in the formation of stable sol.

Example:- (i) Ferric hydroxide sol is obtained when small quantity of ferric chloride solution is added. The peptization action is due to the preferential adsorption of Fe^{+3} ions.

(ii) Aluminium hydroxide sol is obtained when dilute HCl is added. The peptization action is due to the preferential adsorption of Al^{+3} ions. The Al^{+3} ion is generated by the action of HCl on $Al(OH)_3$.

→ Solids in liquids (sols):→

A. Dispersion methods:→

B. Condensation methods:→

1. Double decomposition:→

- A sol of arsenious sulphide is prepared by passing H_2S gas through a dilute solution of arsenious oxide and removing the excess H_2S by boiling.

$$As_2O_3 + H_2S \longrightarrow As_2S_3 + H_2O$$

2. Oxidation:→

- A colloidal sulphur sol is obtained by the oxidation of an aqueous solution of hydrogen sulphide with air or sulphur dioxide.

$$2H_2S + O_2 \longrightarrow 2S + 2H_2O$$

$$2H_2S + SO_2 \longrightarrow 3S + 2H_2O$$

During the oxidation of H_2S to S, complex oxidation reactions occur simultaneously resulting in the formation of polythionic acids. These acids readily get associated with the colloidal particles of sulphur to form bigger colloidal particles called miscells which are thermodynamically more stable than the constituent particles.

In other words, polythionic acids act as stabilizers for the sulphur sol.

- Pentathionic acid, $H_2S_5O_6$ formed during oxidation reaction acts as stabilizing electrolyte.

3. Reduction:→

- Sols of metals such as silver, copper, gold and platinum are obtained by reducing the aqueous solutions of their salts by non-electrolytes formaldehyde, tannin, phenyl hydrazine, carbon monoxide and phophorus.
- Zigmondy prepared gold hydrosol by reducing potassium aurate with formaldehyde. In this reaction, chloroauric acid, $H[AuCl_4]\cdot 4H_2O$, first formed, is made to react with potassium carbonate in an aqueous solution to yield potassium aurate.

$$2H[AuCl_4] + 5K_2CO_3 \longrightarrow 2KAuO_2 + 5CO_2 + 8KCl + H_2O$$

The resulting solution is heated and a dilute solution of formaldehyde is added dropwise when reduction occurs according to the reaction.

$$2KAuO_2 + 2HCHO + K_2CO_3 \xrightarrow{\Delta} 2Au(sol) + 3HCOOK + KHCO_3 + H_2O$$

Potassium aurate, $KAuO_2$, acts as the stabilizer of the red gold sol obtained.

4. Hydrolysis:→

- Colloidal sols of heavy metals are obtained by the hydrolysis of the solutions of their salts. Thus, when a small amount of ferric chloride is added to boiling water, a red-brown sol of ferric hydroxide is obtained.

$$FeCl_3 + 3H_2O \xrightarrow{\Delta} Fe(OH)_3 + 3HCl$$

Boiling promotes the reaction because HCl formed is removed along with water vapours from the system.

- In this reaction, iron oxychloride, $FeOCl$, formed as a result of incomplete hydrolysis of $FeCl_3$, is act as the stabilizer.

$$FeCl_3 + H_2O \longrightarrow FeOCl + 2HCl$$

- The stabilizer can also be $FeCl_3$ or HCl.

5. Exchange of solvents:→

- Sols can also be obtained by exchange of solvents.
- For example, when a concentrated solution of sulphur in alcohol is poured in a large amount of boiling water, the alcohol evaporates leaving behind sulphur particles which rapidly grow into a colloida solution.

→ Purification of colloids (sols):→

— The presence of impurities, particularly the electrolytes, renders the sols unstable. These impurities must be eliminated by suitable methods. Following methods are generally employed.

1. Dialysis:→

- Particles of true solution can easily pass through parchment paper or other fine membranes but colloidal particles, being much larger, cannot pass readily.
- If a mixture, colloidal particles as well as particles of true solution, is placed in a parchment bag which is then held in a wider vessel containing pure water, the substances in true solution pass out while the colloids remain in the bag. The distilled water in the wider vessel is renewed frequently.

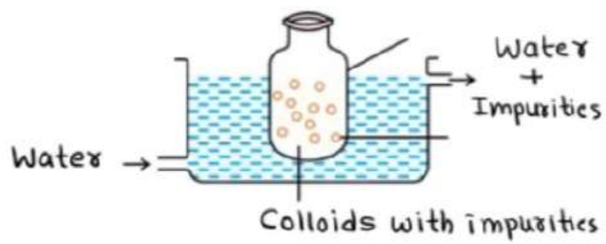


Fig:- Dialysis

- The process of separating substance in colloidal state from those present in true solution with help of fine membrane, is known as dialysis and the membrane used for this purpose is known as dialyser.

2. Electrodialysis:→

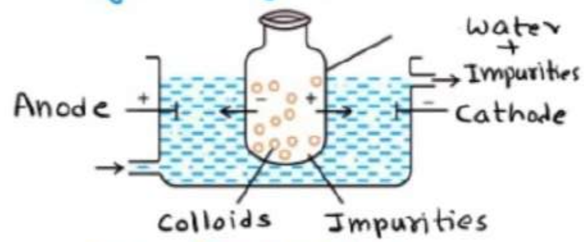


Fig - Electrodylsis

- The process of dialysis is quite slow but it can be quicked by applying an electric field if the substance in true solution is an electrolyte. This process is called electrodialysis.
- The colloidal solution is placed in a bag of suitable membrane while pure water is taken outside.
- The ions present in electrolyte migrat to the oppositly charged electrodes and the colloidal particles held back.

3. Ultra-filtration:→

- The separation of solutes from colloidal system can also be carried out by the process known as ultra-filtration.
- Ordinary filter papers have pores larger than 1 μ (i.e. 1000 mμ) so colloidal particles (size less than 200 mμ) can readily pass through along with ions or molecules in solution.
- But the pores can be made smaller by soaking the filter paper in a solution of gelatin or collodion (collodion is a 4 % solution of nitro-cellulose in a mixture of alcohol and ether) and subsquently hardening them by soaking in formaldehyde. The pores thus become very small and the colloidal particles may be retained on the treated filter paper. The treated filter papers are known as ultra-filters. This process of separating colloids from rest of materials is known as ultra-filtration.
- By using a series of graded ultra-filters, it may be possible to separate colloidal particles of different sizes from one another.
- The process is very slow and sometimes a small pressure is needed to speed up the process.

→ Kinetic properties of sols :→

→ Brownian movement :->

- Robert brown, an English botanist, in 1827 observed that when pollen grains were suspended in water, they showed a continuous motion in zig-zag way when viewed under an ultra-microscope. He named this phenomenon as Brownian movement.
- Later on, all the colloidal system were found to show this movement of the particles of the dispersed phase. The kinetic activity of particles suspended in a liquid is called Brownian movement.

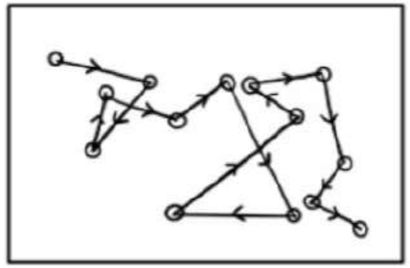


Fig. Brownian movement

- Examples:-
  (i) If a beam of light is allowed to enter a dark room the dust particles are seen dancing in a cone of light.
  (ii) If a sample of diluted milk is observed under an ultra microscope, numerous tiny droplets of fat, swimming and oscillating in all directions will be found.
- The Brownian movement is due to the bombardment of colloidal particles by molecules of dispersion medium which are in constant motion like molecules in a gas. As a result, the colloidal particles aquire almost the same amount of kinetic energy possessed by the molecules of dispersion medium.
- Quantitative measurements reveal that the movement is observable when the particles have a diameter not larger than 0.005 mm. The smaller the particles, the more rapid would be their movement. Hence the Brownian movement cannot be observed in oridary suspension because the mass of each particle in this case is so large that bombardment of particles gets reduced.

- According to Brown, the motion is not dependent upon-
  - (a) Streaming movement of the liquid in which particles are suspended.
  - (b) The mutual attraction or repulsion of the particles.
  - (c) The action of capillary forces.
  - (d) The evaporation of the liquid under the microscope.
- Zigmondy in 1905 investigated a large number of colloids under ultramicroscope and came to the following conclusion-
  - (a) Small particles execute a more rapid, brisk and vigorous motion than the larger ones.
  - (b) The movement does not change with time and remains the same for months and even for years.
  - (c) The movement is affected by the temperature and the movement gets increased with increasing temperature.

→ Importance:-

1. Confirmation of kinetic theory → The Brownian movement is direct demonstration of constant motion of molecules shown by kinetic theory.
2. Stability of Colloidal solution → Brownian movement does not allow the colloidal particles to settle down due to gravity and thus is responsible for their stability.
3. Determination of Avogadro's number → Avagadro's number can be calculated with the help of Brownian movement. Following methods can be used.
   - (a) Perrin's first method
   - (b) Perrin's second method
   - (c) Electrolytic method
   - (d) Radioactive method
   - (e) X-Ray method

→ Optical properties of sols :→

→ Tyndall effect :→

- It was observed by Tyndall, in 1869, that when a beam of light is passed through a true solution, it cannot be seen unless the eye is placed directly in its path.
- However, when same beam of light is passed through a colloidal solution, it becomes visible as bright streak. This phenomenon is known as the Tyndall effect and the illuminated path (streak of light) is known as Tyndall cone.

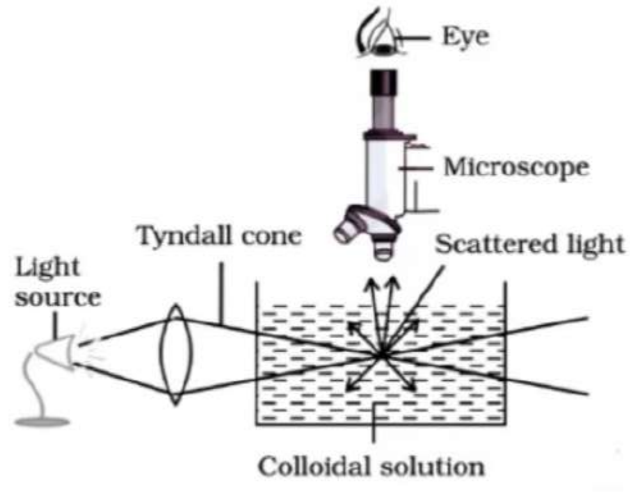


Fig :- Tyndall effect

- This pheomenon is due to scattering of light from surface of colloidal particles.
- In true solutions, there are no particles of sufficiently larger diameter to scatter light and hence beam is invisible.

  Example:- The visibility of dust particles in a semi-darkened room when a sun beam enters or when light is thrown from a light projector.

- The intensity of the scattered light depends on the difference between the refractive indices of dispersed phase and the dispersion medium.

In lyophobic sols, the difference is appreciable and, therefore, the Tyndall effect is quite well defined. In lyophilic sols, the particles are largely solvated. This lowers the difference in the referactive indices of the two phases and hence the Tyndall effect is much weaker.

Thus, in the sols of freshly prepared silicic acid, blood serum, albumin, etc., there is a little or no Tyndall effect.

- According to Rayleigh, the intensity of scattered light can be expressed by the following expression-

$$I = k\left(\frac{\nu^2}{d^2 \lambda^4}\right)$$

where I = Intensity of scattered light k = constant
ν = volume of the particle
d = distance b/w particle and observer
λ = wavelength of scattered light

- It may be noted that we do not see the actual particles; they are too small to be visible. We see only the light scattered by them. Our eye pictures various spots of light as round or spherical particles.

- The Tydall effect has been used by Zsigmondy and Siedentopf in discovering the ultra-microscope. A strong beam of light from an arc lamp or any other source is condensed by system of lenses and passed through the colloidal solution. The scattered beam or Tyndall beam is viewed through a microscope placed right angle to the beam. In this way, the colloidal particles which are two small to be seen under an ordinary microscope, can be detected as spots of light moving irregulary.

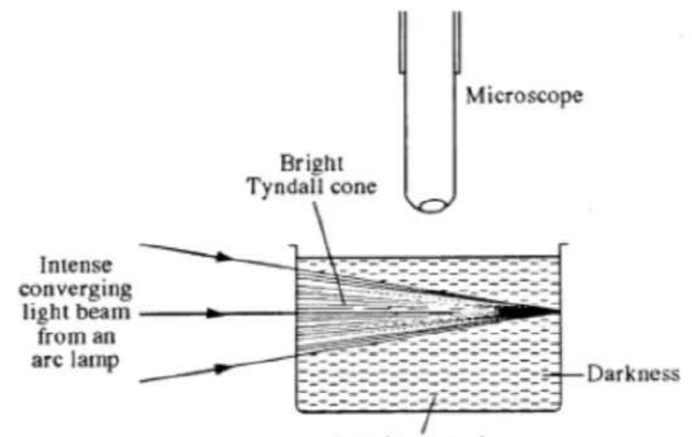


Fig:- Principle of Ultra-microscope

→ Electrical properties of sols :→

→ Charge on Colloidal particles :→

- The most important property of hydrophobic colloidal dispersion is that the particles carry electrical charge.
- All the particles in hydrophobic colloidal system carry the same charge and the dispersion medium has an opposite and equal charge, the system as a whole being electrically neutral.
- The presence of similar charges on colloidal particles is responsible for the stability of colloidal solution. because due to replusion between similar charge, colloidal partical prevented from aggreation.

Electropositive colloids :→ Metal hydroxides (Bi, Pb, Fe), methyl violet and methylene blue.

Electronegative colloids :→ Metal sulphides, prussian blue, metals (Ag, Au, Pt), silicic acid, tannic acid and mastic acid.

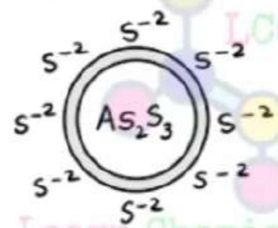
→ The origin of charge on colloidal particles :→

- The origin of charge on colloidal particles has not been completely understood. However, it is believed that the charge on the colloidal particles is due to preferential adsorption of either positive or negative ions on the surface.
- If the particles have a preference to absorb positive ion, they aquire positive charge and if they prefer to adsorb negative ion, then they aquire a negative charge.
- When two or more ions present in the dispersion medium, preferential adsorption of the ion common to the colloidal particle usually takes place.

— Examples:-

(a) Postive charge on ferric hydroxide sol is due to preferential adsorption of Fe^{+3} ions on the surface of particles of ferric hydroxide.

(b) Negative charge on arsenic sulphide sol is due to preferential adsorption of S^{-2} ion on the surface of arsenic sulphide particles.

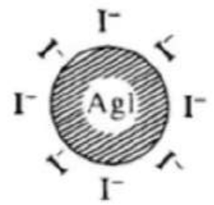


(c) Charge on silver iodide sol :→

$AgNO_3$ (dilute) + NaI (dilute) Excess → Negatively charged sol of AgI is formed due to adsorption of iodide ions.

$AgNO_3$ (dilute) Excess + NaI (dilute) → Positively charged sol of AgI is formed due to adsorption of Ag^+ ions.

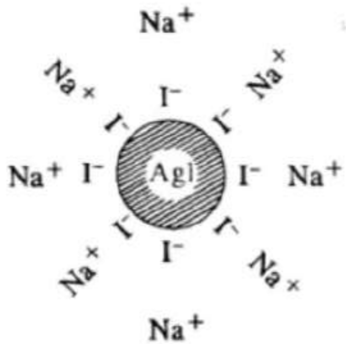
$AgNO_3$ (dilute) + NaI (dilute) (Equal amounts) → No sol is formed.



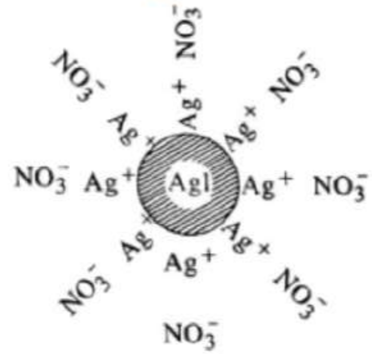
Negatively charged AgI sol

Positively charged AgI sol

- Colloidal particals form a layer by aquiring positive or negative charge on its surface. This first layer attracts counter ions from the medium forming a second layer.



← Electrical double layer →



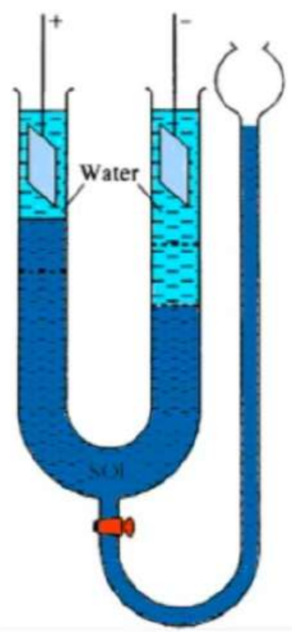
- The combination of the two layers of opposite charges around the colloidal particle is called Helmholtz electrical double layer or simply electrical double layer.
- First layer is called fixed layer and second layer of counter ion is called diffused layer.
- The potential difference between the fixed layer and diffused layer is called zeta potential or electrokinetic potential.

→ Electrokinetic properties:→

- Since the solid particles and the liquid medium carry opposite charges, it is obvious that when an electric field is applied, the particles and the liquid will migrate in opposite directions.
- When experiments are so arranged that the particles can move but not the medium, the phenomenon is called electrophoresis.
- When experiments are designed in such a way that the medium can move but not the particles, the phenomenon is called electro-osmosis.

→ Electrophoresis:→

- The electrophoretic effect can be studied by the simple apparatus shown in figure.
- It consist of a U-tube provided with a stop-cock through which it is connected to a funnel-shaped reservior.
- A small amount of water is first placed in U-tube and a resonable quantity of the sol is taken in the reservior. The stop-cock is then slightly opened and the reservior gradually raised so as to introduce the sol into the U-tube gently.
- The water is displaced upwards producing a sharp boundary in each arm.
- A voltage of 50-200 volts is applied through platinum electrodes.
- The movement of the particles can be observed by position of the boundary.
- When the particles are negatively charged, the boundary on the negative electrode side is seen to move down and that on the positive electrode side to move up showing that the particles move towards the positive electrode.



- Thus, by noting the direction of motion of the particles in the electric field, it is possible to determine the sign of the charge carried by the particles.
- It is also possible by this technique to determine the rate at which colloidal particles migrate in electric field. This rate is expressed in terms of electrophoretic mobility of colloidal particles.
- The electrophoretic mobility of colloidal particles is defined as the distance travelled by them in one second under a potential gradient of one volt per centimeter. The electrophoretic mobilities of colloidal particles are of the same order as those of ions under similar conditions, that is, of the order of $(10-60) \times 10^{-5}$ cm/sec/volt/cm.
- Since different colloidal materials have different mobilities, it is possible to separate them from one another from their mixtures. This method has been used for the fractionation of proteins, polysaccharides, nucleic acids and other complex substances.

→ Electrokinetic properties:→

ⓐ Electrophoresis

ⓑ Electro-osmosis:→

- When electrophoresis of dispersed particles in a colloidal system is prevented by some suitable means, it is observed that the dispersion medium itself begins to move in an electric field. This phenomenon is called electro-osmosis.
- A simple apparatus used for electro-osmosis is shown in figure.

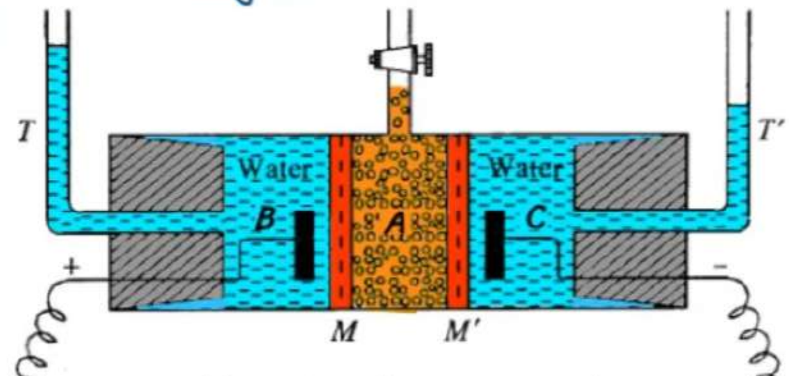


Fig:- Electro-osmosis

- The colloidal system is placed in central compartment A which is separated from compartments B and C by the dialysing membranes M and M′. Compartments B and C are filled with water. The water in the compartments B and C also extends to the side tubes T and T′.
- The membranes prevent the movement of the colloidal particles. Therefore, when a potential difference is applied across the electrodes, the water begins to move.
- If the particles carry positive charge, the water will carry negative charge. Therefore, it would start moving towards the anode and hence level of water in the side tub T would be rise.
- If, the particles carry negative charge, the water which carries positive charge, will start moving towards the cathode and the level of water in the side tube T′ would start rising.

→ <u>Stability of Colloids (sols)</u> :→

- In case of lyophobic colloids, the stability is due to electrical charge present on the colloidal particles whereas the stability of the lyophilic colloids depends upon both the electrical charge and solvation.
- In a lyophobic sol, the charge on all the colloidal particles is of same sign, the replusive forces prevent the particles from approching sufficiently close to one another and to combine and coagulate.

  The magnitude of replusive forces depends upon the magnitude of the surface charge and thickness of the electrical double layer. These factors also determines the value of the zeta potential which actually governs the stability of the colloidal system.

  The value of zeta potential decreases when an ion of opposite charge to that of the colloidal particle is adsorbed.

  If zeta potential is small, the resultant potential energy is negative so that the van der Waals attraction predominates over the electrostatic replusion and the sol coagulates rapidly.

- In case of lyophilic sols, solvation plays a very important role. since the colloidal particles are enclosed in a solvent 'cage', the cage serves as a barrier preventing the particles from combining to form aggregates.
- In case of lyophobic sols, removal of colloidal particles charge causes coagulation while in the case of lyophilic sols, the charge removal may not necessarily result in coagualtion though it may decrease the stability of the sol.

- The concentration at which the colloidal particles have no charge is known as the isoelectric point.

→ Theories of stability of sols :→

1. Powis theory:→

- According to Powis, coagulation is caused only when charge on the colloidal particles is removed. The charge on the colloidal particles need not to remove completely. A lowering of potential of the interface to certain value called the critical potential which is essential to bring about the coagulation.

2. Perrin and Rice theory:→

- They explained stability of sols in terms of thermodynamics and suggested that stability of the sol is related to the negative free surface energy of the double layer.

3. Sovation theory:→

- Kruyt showed that solvation of colloids is related to the stability of the sols. Every lyophilic sol has a thin layer of solvent around its colloidal particles which do not allow the sol to coagulate easily.

4. Gyemant - Lewis theory:→

- According to them, suface tension and charge of sol are responsible for the stability of sol.

→ Thermodynamic stability of sols:→

- The substances which form lyophilic sols are spontaneously soluble in the solvent and form stable system. These sols are, therefore, thermodynamically stable
- The substances which form lyophobic sols are not spontaneously soluble in the solvent and required special methods. These sols are, therefore thermodynamically unstable.

- The unstable system has greater potential energy than the stable system.
- If the number of particles is N, the potential energy of the colloidal system (A) is :-

$$A = 4\pi r^2 \gamma K$$

where r = Radius of each particle

γ = Surface tension of the liquid.

→ **Factors affecting the stability of sols :→**

1. Brownian movement
2. Addition of electrolyte
3. Rate of addition of electrolyte
4. Effect of dilution
5. Effect of temperature
6. Ultraviolet radiation and x-rays
7. Stabilsing by protective films
8. Ultrasonic irradiation
9. Boiling and freezing
10. Mechanical agitation.

→ Protective action or Protection of colloids :→

- Lyophilic sols are more stable than lyophobic sols.
- When certain lyophilic colloid is added to a lyophobic colloids, the stability of lyophobic sol is increased. Thus lyophobic sols are less sensitive to precipitating action of an electrolyte, i.e. the addition of the small amounts of electrolytes does not cause the precipitation of the lyophobic sols. In other words, lyophilic colloids protect a lyophobic colloid from precipitation by the action of electrolytes. Such lyophilic colloids or substances are known as protective colloids and the phenomenon is called protection.
- Protective colloids not only increases the stability of lyophobic colloids but they also convert an irreversible colloid (lyophobic) into reversible colloide.

Examples of protective colloids → gum, gelatin, agar-agar etc.

Examples of protective action.

(i) Soluble substances like $Ca_3(PO_4)_2$ are held as colloids in blood due to protective action of protein in blood.

(ii) To prevent clogging in pens; superior pen inks contain some protective colloids.

→ Explanation of protective action:→

- The particles of the protective colloid get adsorbed on the particles of lyophobic colloids, thereby, forming a protective layer around it.
- The protective layer prevents the precipitating ions from coming in contact with the colloidal particles.

→ Theories of protective action:→

1. Bechhold theory:→

- According to Bechhold, protective action is due to homogeneous encircling of the suspended particles by the particles of the protective colloids.
  But according Zsigmondy, this theroy can be accepted in case of coarse suspension.

2. Billitzer's theory:→

- According to Billitzer, protective action is due to adsorption of any precipitating electro-lytes by the protective colloids, and not by the union of the particles of the two colloids. This was disproved by Zsigmondy who suggested the mutual adsorption of the particles of the two sols.

3. Williams and Chang theory:→

- According to them, the protective action is due to fact that negatively charged lyophilic colloids will form a coating around the negatively charged lyophobic colloid. Similarly positively charged lyophilic colloids will form a coating around positively charged lyphobic colloids.
  In other words, lyophilic substance envelops the particles of the lyophobic colloids

→ Applications of protective action:→

- Preparation of pharmaceutical products.
- preparation of silver sol which is used in medicines or as an ointment.
- Stabilisation of colloidal suspension.

→ Gold number:→

- The protective character of various lyophilic substances can be expressed quantitatively by gold number.
- The protective character of lyophilic colloid depends upon the nature of the substance.
- According to Zsigmondy, gold number may be defined as:

  "The number of the milligrams of the protective colloid must be added to 10 ml of a given gold sol so as to prevent its precipitation by addition of 1ml of 10% NaCl solution."

  OR

  "The largest number of milligrams of a protective colloid which, when added to 10 ml of a special standard gold sol, just fails to prevent the colour change from red to blue upon the addition of 1 ml of 10% sodium chloride solution."
- Smaller the gold number, higher the protective power of a colloid.

$$\text{Gold number} \propto \frac{1}{\text{protective power of colloid}}$$

- The protective action of a lyophilic sol depends upon several factors such as sol dispersity, the molar mass of the lyophilic sol, the pH of the solution at which experiment is carried out, and so on.
- It is common to use sol other than gold sols to determine the protective action of high molar mass colloid. Thus, silver, sulphur, prussian blue etc. sols have been used and the corresponding 'numbers' determined accordingly.

Protective Action of High Molar Mass Lyophilic Colloids on Some Hydrophobic Sols

Protective Colloids	Numbers					
	Gold	Silver	Sulphur	Iron oxide	Rubin	Prussian blue
Gelatin	0·01	0·035	0·00012	5	2·5	0·05
Dextrin	20	100	0·125	20	.....	250
Saponin	115	35	0·015	11·5	.....	2·5
Potato starch	20	.....	.....	.....	20	.....
Haemoglobin	0·03–0·07	.....	.....	.....	0·8	....
Egg albumin	2·5	1·5	0·025	15	2·0	25
Gum arabic	0·5	1·25	0·125	20	.....	5

→ Coagulation or Flocculation :→

- The colloidal sols are stable by the presence of electric charges on the colloidal particles. Because of the electric repulsion the particles do not come close to one another and combine.
- The removal of charge of colloidal particles will cause the aggregation of particles and hence precipitation.
- The process by which the particles of the disperced phase in a sol are precipited is known as coagulation or flocculation.
- The phenomenon of changing colloidal state to a suspended state is known as coagulation, flocculation or precipitation of colloidal solutions.
- The precipitate after being coagulated is known as coagulum.

→ Coagulation of colloidal sols :→

1. By the action of electrolyte :→

- In this method, large amount of electrolytes are added to the sols which cause precipitation. This is due to fact the colloidal particles take up the ion whose charges are oppositie to that on colloidal particles. With the result that the charge on colloidal particles is neutrilised and coagulation takes place.
- The ion of opposite charge which cause precipitation is called active ion.

2. By the mutual action of sols :→

- When two sols carring opposite charges are mixed together in suitable proportions, mutual precipitation occurs.

3. By persistent dialysis:→

- The traces of electrolytes are essential for the stability of sols.
- If the sols are subjected to prolonged dialysis, these traces of electrolytes also pass out through the dialyser and the colloids becomes unstable.

4. Coagulation by mechanical methods:→

- Violent stirring of a sol may coagulate it.
- Sols may also coagulate due to vibratory action caused by ultrasound.
- Vibratory coagulation is used to manufacture of pastes and other similar materials.

→ Theories of coagulation:→

1. Adsorption theory:→

- Freundlich developed a theory according to which coagulation occurs by the adsorption of ions of ions of opposite charge to that of colloidal particles.

2. Critical potential theory:→

- Gouy, Burton, Debye and Huckel explained the phenomenon of coagulation on the basis of electrical double layer.
- According to them the ions which are responsible for precipitation are adsorbed on the fixed part of the double layer.

3. Verwey and Overbeek's theory:→

- According to these coworkers the coagulation takes place when the particles of sol approach each other.

4. Ostwald theory:→

- According to Ostwald, the coagulation does not depend upon the discharge of particles but due to some physical properties of the dispersion medium.

→ Factors affecting coagulation:→

- Nature of the sol.
- Nature of charge on sol particles.
- Valency of precipitating ions.
- The mode of coagulation.
- Time allowed for coagulation.
- Concn of electrolyte.
- The ratio of surface to mass of dispersed phase.
- Temperature.
- Addition of dehydrants.
- Centrifugal forces.

→ Hardy - Schulze law :→

- This law explains about the coagulation effect of electrolytes on lyophobic sols.
- According to this law, the greater the valency of the active ion, greater is the power to cause coagulation.
- In case of positively sol the coagulating power of anions is in the order of

$$[Fe(CN)_6]^{4-} > PO_4^{-3} > SO_4^{-2} > Cl^-$$

- In case of negatively sol the coagulating power of cations is in the order of

$$Al^{+3} > Mg^{+2} > Na^+$$

- Quantitatively, the power varies directly as the square of the valency of the ion. Thus a Mg^{+2} ion is 4 times more effective than Na^+ and Al^{+3} ion is 9 times more effective than Na^+.
- The minimum concⁿ of an electrolyte required to cause coagulation or flocculation of a sol is called its flocculation value. It expressed in terms of milimoles per litre of the electrolyte.

Flocculation Values of Different Electrolytes

Arsenic Sulphide Sol			Ferric Hydroxide Sol		
Electrolyte	Cation Valency	Flocc. Value (millimoles per litre)	Electrolyte	Anion Valency	Flocc. Value (millimoles per litre)
NaCl	1	52	HCl	1	132
KCl	1	52	KBr	1	138
HCl	1	30	KNO_3	1	132
K_2SO_4	1	64	$KBrO_3$	1	31
$MgSO_4$	2	0·72	K_2CrO_4	2	0·315
$CaCl_2$	2	0·69	K_2SO_4	2	0·210
$ZnCl_2$	2	0·68	$K_2C_2O_4$	2	0·238
$AlCl_3$	3	0·093	$K_3[Fe(CN)_6]$	3	0·096

→ Liquids in liquids (Emulsions):→

- Emulsions are liquid-liquid colloidal system. Which consist of immiscible liquids.
- An emulsion is a heterogeneous system consisting of more than one immiscible liquids dispersed in one another in form of droplets whose diameter, in generel more than 0.1 μ.
- An emulsion is a stable suspension of a liquid of certain size in another immiscible liquid.

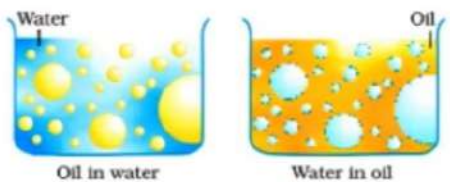
  Example:- Milk is an emulsion in which particles of liquid fat are dispersed in water.
- Emulsion droplets can be observed under an ordinary microscope and sometimes even with a magnifying lens.

→ Types of emulsions:→

(a) Oil in water (O/W) type:→

- In these emulsions oil forms the dispersed phase and water forms the dispersion medium.
- These are also called aqueous emulsions.

  Example:- Milk, Vanishing cream etc.



(b) Water in oil (W/O) type:→

- In these emulsions water is in the dispersed phase and oil in the dispersion medium.
- These are also called oil emulsions.

  Example:- Butter, cold cream etc.

- In addition to above one another type is called multiple emulsion. A multiple emulsion is one in which both types of emulsion (i.e. O/W and W/O) exist simultaneously. It can be denoted as W/O/W emulsion.

→ Types of colloids on the basis of the size of dispersed particles:→

(a) Macroemulsions:→

- Opaque emulsions with particle size > 400 nm.
- Easily visible under a microscope.
- Two types, o/w and w/o

(b) Microemulsions:→

- Transparent emulsions with particle size < 100 nm.
- May be o/w and w/o

(c) Miniemulsions:→

- Blue-white emulsions with particle size 100-400 nm.

→ Factors determining the type of emulsions:→

(a) Relative proportion of the two liquids:→

- The liquid present in excess forms the dispersion medium.

(b) Surface tension of the two liquids:→

- The liquid with greater tendency to forms spherical droplets and hence the dispersed phase.

→ Inversion of emulsions:→

- The change of o/w emulsion into the w/o type or vice versa is called the inversion of phase or inversion of emulsion and the emulsion is called inverted.

✱ Emulsions also show Brownion movement and Tyndall effect.

→ Preparation of emulsions:→

- Preparation of emulsion is called emulsification.
- Emulsions are obtained by spraying mixtures of phases through narrow nozzles or in counter-rotary agitators.
- Emulsions can also be prepared by using ultrasonic waves.
- Neutral soaps which are insoluble in hydrocarbons but soluble in water give oil in water emulsions.
- Acid soaps which are more soluble in hydrocarbons give water in oil emulsions.
- Emulsions can also be prepared by those stabilizers which are insoluble in both phases.
  Clay, glass powder, $CaCO_3$ and pyrites are easily wetted by water and give rise to aqueous emulsion while lamp black, which is more easily wetted by an oil, gives oily emulsion.
- A condensation method given by Summer has been employed in preparation of concentrated o/w emulsions.

→ Emulsifiers :→

- In order to prepare stable emulsions, it is important to add a third component known as emulsifier or emulsifying agent in suitable amount.
- Examples of emulsifiers :-
  (1) Long chain compounds with polar groups such as soap, sulphonic acid sulphates.
  (2) Most of the lyophilic colloids such as glue, gelatin etc. also act as emulsifiers.
  (3) Certain insoluble powders such as clay, lamp black, etc.
  (4) Soluble substances like iodine also act as emulsifers.

→ Role of an emulsifier :→

- An emulsifier may acts in two ways :-

(1) It may be more soluble in one liquid than in other :→

- In this case it will form a protective film around the drops of this liquid in which it is less soluble and thus prevent them from coming together.

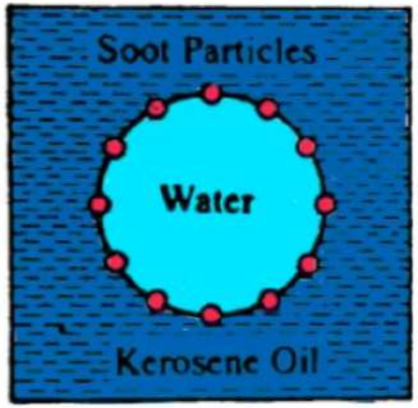
Example :- (a) Emulsification of o/w type emulsion by neutral soap which is more soluble in water.
(b) Emulsification of w/o type emulsion by acidic soap which is more soluble in oil.

(a)

(b)

2. The emulsifier may be insoluble in both the liquids but not unequally wetted by two.

- For example lamp black or soot particles are wetted more by kerosene oil than water. In this the surface of solid is more in contact with the liquid by which is wetted most.



→ Factors affecting stability of an emulsion:→

- Electric charge of droplets.
- Thickness and compactness of the protecting film or interfacial layer.
- Viscosity of the dispersion medium.
- Density difference between the two liquids.

→ Bancroft rule:→

- O/W emulsions are produced by emulsifying agent that are more soluble in water than in oil phase whereas W/O emulsions are produced by emulsifying agent that are more soluble in oil than in water. This is known as Bancroft rule.

→ Demulsification:→

- The process of separating the two constituent liquids of the emulsion into separate layers is called demulsification.

→ Liquids in solid (Gel) :→

- Gel represents a liquid-solid system, i.e., a liquid dispersed in a solid.
- According to Ostwald, a gel is a colloidal semi solid system rich in liquid phase, Thus a gel is having two components one is solid and other is a liquid.
- Several lyophilic sols and a few lyophobic sols as well, when coagulated under certain conditions, change into a semi-rigid mass, enclosing the entire amount of the liquid within itself. Such a product is called a gel.
- The process of transformation of a sol into a gel is known as gelation.

  Examples:- Silicic acid gel in water, sodium oleate gel in water, gelatin in water etc.

→ Jelly :→

- Jelly is the common name of a gel.
- According to McBain a gel may be defined as a colloidal system consisting of the both liquid phases rich and dry system, but a jelly is an elastic, coherent system which is very rich in liquid phase.

  Examples:- Fruit jellies.

→ Xerogels :→

- This term is related to dry gels.

  Examples:- Gelatin sheet, cellophane foil, a piece of dry gum arabic etc.
- Xerogels have less liquid than solid. The jellies have 95% or more liquid. Gelatin jellies have 95 to 99% of water. Similarly agar-agar jellies have 99.8% water. Fibrin clots contain the very small amount of water.

→ Classification of gels :→

- The gels may be classified as-

(a) On the basis of dispersion medium :-

(i) Alcogel :- Dispersion medium is alcohol.

(ii) Benzogel:- Dispersion medium is benzene.

(iii) Hydrogel :- Dispersion medium is water.

(b) On the basis of size of particles: -

- This classification of gels is done on the basis of size of particles which form the frame work. Hence a gel may be colloidal or coarse.
- The agar-agar is the colloidal gel.

(c) On the basis of chemical composition:-

(i) Inorganic gel :- Contains inorganic solvent.

(ii) Organic gel or organogel :- Contains organic solvent.

(d) On the basis of their properties: -

(i) Elastic or heat reversible gels:-

- If these gels are dehydrated they convert into the elastic solid form. The gel is again regenerated by adding water.
- In these the fibrils composing the gel are flexible. On hydration these fibrils expand again to form the gel again.

Example:- Gelatin gel, agar-agar etc.

(ii) Non-elastic or irreversible type gels:-

- These have non-elastic property and they cannot be regenerated again when dried.
- The rigidity of these gels increases with time.

  Example:- sols of silicic acid or alumina.

(e) Thixotropic gels:-

- These are the gels which when shaken form a sol and on standing are converted into the form of the gel. The gels of this nature are termed as thixotropic gels and this phenomenon of sol-gel transformation is termed as thixotropy.
- The gels which are prepared on cooling exhibit such a property.
- The frame-work of such gel is so weak that is broken on shaking.

→ **Preparation of gels:→**

(i) By coagulation or decrease in solubility:-

- Many colloidal solutions can be transformed in the form of gel by coagulation.

  Example:- Sol of pectin can be converted into gel by the addition of alcohol or sugar.

(ii) By chemical reaction:→

- The gels can also be prepared by chemical reactions of concentrated solutions if one of the products of the reaction is insoluble and the particles are having the tendency to aggregate in the form of linear colloid.

  Example:- $BaSO_4$ gel is prepared by shaking saturated solution of barium thiocyanate and manganous sulphate.

  Aluminium hydroxide gel is prepared by mixing a concentrated solution of aluminium salt and ammonium hydroxide.

(iii) By cooling of colloidal solution:→

- The gels of some sols can be prepared by cooling their hot solutions.

  Example:- Agar-agar, soap are soluble in hot solvents, when they are cooled they form gel.

- This type of gelation depends on the following factors:-

(a) The temperature of gelation.
(b) The time of gelation
(c) Viscosity of the medium.
(d) Minimum concentration of the colloid.

(iv) By double decomposition:→

- The gels of some sols can be prepared by the process of double decomposition.

Example:- Silicic acid gel can be prepared by adding water to sodium silicate.

(v) By exchange of solvent:→

- In the preparation of some of the gels, the gelation takes place by the exchange of the solvent in which sol is insoluble.

Example:- In case of calcium acetate gel, pure alcohol can be added to the aqueous solution of calcium acetate, in this way whole of the calcium acetate goes into alcohol which then sets in the form of a gel.

→ Properties of gels:→

(1) Electrical conductivity:→

- According to Kistler (1931) no change of electrical conductivity takes place when a sol converts into a gel. This property reveals that there is simply the change of state during this conversion.

(2) Optical properties:→

- According to Leick gels exhibit the property of double refraction. It is due to internal tension in gel structure.
- Gels also exhibit property of polarised light.
- Leick determined the refractive indices of different gelatin gels.

(3) Elastic properties:→

- Gels show elastic properties like compressibility, flexibility, tensile strength etc.

(4) Swelling or Imbibition :→

- When elastic gels placed in water, they absorb water and undergo swelling. This phenomenon is known as imbibition or swelling. Due to imbibition volume of gel increases.

Example:- When gelatin sheet is immersed in water it absorbs water and swells up.
Piece of vulcanised rubber swells up when placed in chloroform or in benzene.

- The extent of swelling depends on the following:-

(a) Temperature of the system
(b) pH of the solution
(c) Nature of gel

5. Syneresis :→

- When elastic or non-elastic gels are allowed to stand they undergo shrinkage in volume. This phenomenon is called syneresis.
  Example:- Perspiring of cheese
- The degree of syneresis depends upon following factors:-
  (a) Temperature
  (b) Pressure of electrolyte
  (c) Dispersion medium
  (d) State of the gel

→ Applications of colloids:→

- The important applications of colloids are given below-

1. Medicines:→

- Colloidal medicines being very finely subdivided can be easily adsorbable by the body and they are thus more effective.

Example:- Argyrol- an eye lotion is a colloidal solution of silver protected by gelatin.
Colloidal gold and calcium are used as tonics.
Colloidal sulphur is a germ killer.
Codliver oil is used as tonic is an emulsion.
Milk of magnesia, an emulsion, it used for stomach troubles.

2. In Industry:→

(a) Purification of water:→

- Negatively charged colloidal clay particles present in river water removed by coagulation by addition of alum. The Al^{+3} ions responsible for precipitation.

(b) Tanning of leather:→

- Tanning is a process which imparts hardness to leather.
- Skins and hids are positively charged colloidal sols of proteins. These are coagulated by addition of negatively charged sol of tannin present in tree bark. By this process, leather gets hardened and becomes fit for further use.
- Salts of chromium have also been used in place of tannin. The process is known as chrome tanning. The leather obtained by chrome tanning is more soft and can take up polish easily.

(c) In laundary :→

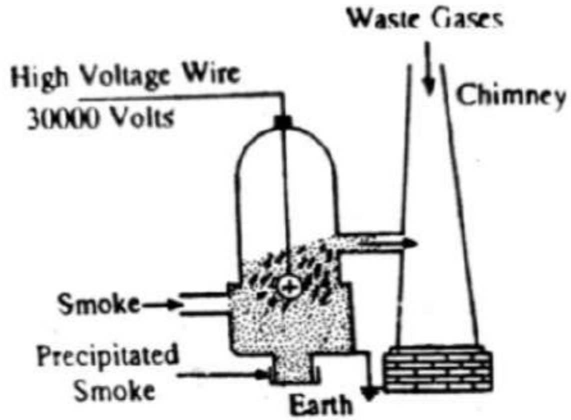
- The cleansing action of soap is explained by formation of an emulsion with the dirt and grease of the dirty clothes. The emulsion is easily washed away by water.

(d) Rubber industry:→

- Latex obtained from the rubber trees is an emulsion of negative rubber particles dispersed in water.

(e) Removal of carbon from smoke – Cottrell's precipitator:→

- Carbon particles in air are colloidal in nature and carry negative charge. Air from chimney of an industrial plant before letting out into atomsphere is passed through Cottrell's precipitator maintained at high potential difference(about 30-50k volts). The removal of carbon particles from air involves the principle of electrophoresis. Carbon particles get precipited by losing their charge and thus, the air which finally comes out is free from carbon particles.



(f) Sewage disposal:→

- Sewage is a colloidal system where dirt, mud etc are dispersed in water.
- Sewage is passed through big tanks fitted with electrods. Dirt particles are lose their charge and get settle down.
- The dirt deposited at the electrodes is removed and used as manure.

(g) Ceramic industry:→

- The earth and clays are typical gels containing aluminium silicate and iron hydroxide mixed with organic colloids. The properties of ceramic clay is due to the presence of colloidal substance.

(h) Dyeing industry:→

- The cotton, silk or wool fibres almost possess the gel structures.
- Dyes and mordants employed for dyeing are all colloids.
  Example:- $Al(OH)_3$, $SnCl_2$, tannin etc. are mordants.

(i) Manufacture of Acheson's graphite:→

- Acheson's graphite is a lubricant and is colloidal in nature.

(j) Photographic plates and papers:→

- Sensitive emulsions are deposited on photographic plates/films are the fine suspensions of silver bromide in gelatin.

(3) In Nature:→

(a) Blue colour of the sky:→

- It is due to the scattering of blue light by colloidal dust particles in air.

(b) Tails of comets:→

- Comets fly with very high velocity and it has been found that some solid particles are left behind. These particles scatter light and are visible as the tyndall cone which forms the tail of the comet seen in the sky.

(c) Formation of delta:→

- Formation of delta at the meeting place of river with sea is due to the coagulation of negatively charged clay particles by the positively charged Na, K or Mg ions present in sea water.

(d) Rain:→

- The rain is caused by the aggregation of colloidal water particles dispersed in air.
- The coagulation of the colloidal water in air may be caused by the cold air or when the oppositely charged clouds meet.
- It is possible to cause artificial rain by throwing electrified sand in the air or some colloidal solution having particles, with charge opposite to that on the clouds.

(e) Blood:→

- Blood is a colloidal system, having albuminoid substance as the dispersed phase carrying a negative charge.
- Bleeding can be stopped by application of alum or ferric chloride. By the addition of Al^{+3} or Fe^{+3}, the coagulation of the blood takes place and bleeding stops.

(f) Articles of daily use:→

- Milk is an emulsion of fat in water (o/w type) stabilised by casein.
- Butter is an emulsion of water dispersed in fat (w/o type).
- Ice cream is ice dispersed in cream.

(4) Analytical applications:→

(a) Qualitative and Quantitative analysis:→

(i) In volumetric analysis:→

- Hydrophilic colloids can alter the end point of titration, e.g., in a titration of HCl & NaOH, the amount of deviation in the end point increases with increasing amounts of colloids.
- In the determination of silver by Mohr's method (precipitation method) the phenomenon of adsorption is involved.

(ii) In gravimetric analysis:→

- In this analysis crystalline precipitate are needed and the procedure thus adopted gives rise to the formation of sufficiently bigger particles because smaller particles may pass through the filter paper.
- In oreder to prevent coprecipitation and post precipitation, it is necessary to precipitate fairly dilute solutions in hot conditions.

(iii) In qualitative analysis:→

- In this analysis organic matters should be destroyed, otherwise they will form protective colloids and prevent the precipitation of various precipitates.

(b) Identification of traces of noble metals:→

- Noble metals such as pt, Au, Ag etc., when present in the colloidal form produce very bright and intense colours. These metals identified on the basis of different colours.

(c) Distinction of natural from artificial honey:→

- Natural honey is also colloidal in nature.
- Ley's test is used for distinction between natural and artificial honey.

Natural honey + Ammonical $AgNO_3$ reagent → Reddish yellow colour due to presence of traces of albumin or etheral oil.

Artificial honey + Ammonical $AgNO_3$ reagent → Dark yellow or greenish precipitate.

(5) Miscellaneous applications:→

(i) Fertility of soils:→

- Good fertile soil contains plants uptake materials in the form of colloids.

(b) In war:→

- Smoke screens in war are obtained by dispersing colloidal TiO_2 particles in air.
- Animal charcoal is used in gas masks for the adsorption of poisonous gases.

(c) Metallurgy of alloys:→

- The properties of alloys are modified by the presence of colloidal substances.

(d) Concentration of ores:→

- During froth flotation process employed for the concentration of sulphides ores, emulsion is formed.