process of ... the aggregates involved, ... and semi-permeability of the membrane.

Fig. 8.3. Dialysis apparatus

(ii) **Ultrafiltration** :-

This is another important method for purifying sols. The process of ultrafiltration is similar to the ordinary filtration of an precipitate except with the difference that the membrane used here is designed in such a way that it will permit the passage of only electrolytes and medium, and not of colloidal particles. Colloidal particles thus can be separated from the medium containing electrolytes. Such membranes are made by impregnating ordinary filter paper with collodion or a regenerated cellulose. Since ultrafiltration membranes are of delicate constitution and can be easily broken, they are generally supported on a ... quickened by using pre...

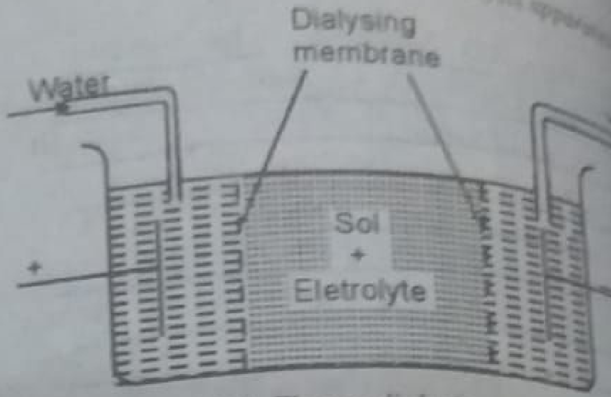

Fig. 8.4. Electro-dialysis apparatus

8.5. PROPERTIES OF COLLOIDS

1. Color

Colloidal solutions are invariably colored. The color of the sol depends on the size and shape of the colloidal particles, the absorption power of the dispersed phase and dispersion medium and the wavelength of the light falling on it. For example a gold sol with different particle-size shows different colors.

2. Heterogeneity

Colloidal particles being larger than the molecules or ions, form heterogeneous mixtures consisting of particles of dispersed phase and dispersion medium.

3. Non-Settling

Colloidal solutions are quite stable systems and the suspended particles remain suspended indefinitely. Only some large particles may settle but very slowly.

Filtrability

Colloidal particles pass through an ordinary filter paper, which cannot, therefore, for removing the dispersed phase. Ultrafilters are used for the purpose. These are of unglazed porcelain which retain the colloidal particles and allow the of dispersion medium to pass through.

Tyndall Effect - Optical Properties

An important characteristic of colloids is the scattering of light. If a beam of passed through a medium which is optically clear that is, it contains no particles size than the molecules of true solution; it is difficult to detect the path of light. When light is passed through a colloidal system, in which the particle size is large, are scattered. This phenomenon of scattering of light by particles was studied by and is generally known as the *Tyndall Effect*. The bright cone of scattered light is Tyndall cone. A true solution does not show the Tyndal effect and is said to be optically void.

If a beam of light is passed through a colloidal solution in a dark room, solution becomes luminescent when viewed through a microscopic at right angle to the path of incident light. Quantitative study of the Tyndall effect and other kinetic properties has rendered possible with the help of ultramicroscope introduced by *Zsigmondy* in 1903. The arrangement of the system is shown in Fig. 8.5.

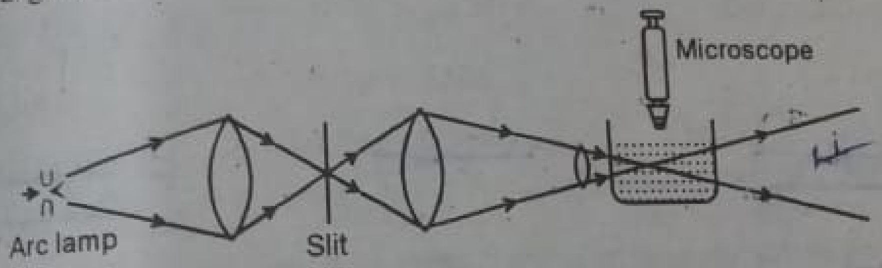

Fig. 8.5. Arrangement of ultramicroscope.

A strong beam of light is passed through a cell containing colloidal solution and viewed through a microscope. Zsigmondy showed that if the colloidal particles are seen from directions at right angles to the incident light, the colloidal particles appear as bright spot against a dark background.

Brownian Movement - Kinetic Properties

Robert Brown (1927), a botanist, observed that pollen grains when suspended in a liquid and are observed under a microscope exhibit a ceaseless random motion and traveled a zig-zag path. It has been found that colloidal particles exhibit random zig-zag motion when seen under ultramicroscope. This random zig-zag motion of colloidal particles is known as *Brownian movement*. This movement is due to the bombardment of the colloidal particles by the molecules of the dispersion medium. When an

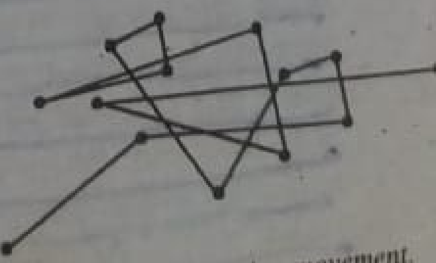

Fig. 8.6. Brownian movement.

unequal number of molecules of the medium strike the colloidal particle from opposite directions, then the colloidal particle begins to start his random motion. The Brownian movement of colloidal particles counteracts the force of gravity acting on them and is thus responsible to a certain extent for the stability of the colloids.

7. Charge on Colloidal Particles - Electrical Properties

Colloidal particles always carry some charge otherwise the colloidal solution would be unstable. The charge on the colloidal particles is of the same type in a colloidal solution. Certain colloidal solutions such as those of ferric hydroxide hydrosol are positively charged, whereas particles of arsenious sulphide hydrosol are negatively charged. Proteins are amphoteric and may be either positively or negatively charged depending on the pH of the solution. The charge on the particles may be due to:

(*a*) **The presence of acidic and basic groups.** The charge in case of proteins, amino acids, polypeptides etc. can be explained due to the presence of acidic (–COOH) and basic (–NH_2) groups in the molecule. In acidic solution, the molecules will have positive charge due to the protonation of basic groups while in alkaline solution the molecules will be negatively charged due to ionization of acidic groups as shown below.

$$\underset{\text{Negative charge in alkaline medium}}{\mathrm{R{-}CH(NH_2){-}COO^-}} \xleftarrow{OH^-} \underset{\text{Protein molecule}}{\mathrm{R{-}CH(NH_2){-}COOH}} \xrightarrow{H^+} \underset{\text{Positive charge in acidic medium}}{\mathrm{R{-}CH(NH_3^+){-}COOH}}$$

It is clear that the charge in such cases is a function of pH of the medium. The pH at which the net charge on the molecule is zero is called the *isoelectric point*. The molecules at the isoelectric point exist as *Zwitter ions*. A lyophilic colloid has minimum stability at this pH.

(*b*) **Due to the dissociation of the surface molecules.** Colloidal electrolytes such as soaps, $C_{15}H_{31}COO^-Na^+$ (sodium palmitate) dissociate in solution giving ions. The hydrocarbon parts of the ions have a marked affinity for one another and they are drawn together. Thus the negative ions (the palmitate ions) aggregate to form an ionic micelle which is of colloidal size. This accounts for the presence of negative charge on the colloidal soap particles.

(*c*) **Due to preferential adsorption of ions.** The charge on the colloidal particles in some cases results from adsorption of either positive or negative ions from the medium in which they are prepared. The particles constituting the dispersed phase of a colloidal solution adsorb those ions preferentially which are common with their own lattice ions. For example, if silver nitrate solution is added to potassium iodide solution, the precipitated silver iodide (AgI) will adsorb iodide ions (I^-) from the dispersion medium and negatively charged colloidal solution will result. However, if silver iodide is formed by adding potassium iodide to silver nitrate solution, we will get a positively charged suspension due to the preferential adsorption of silver ions (Ag^+) which are present in the dispersion medium. This phenomenon forms the basis of the use of adsorption indicators (e.g., eosin, fluorescein etc.) in volumetric analysis.

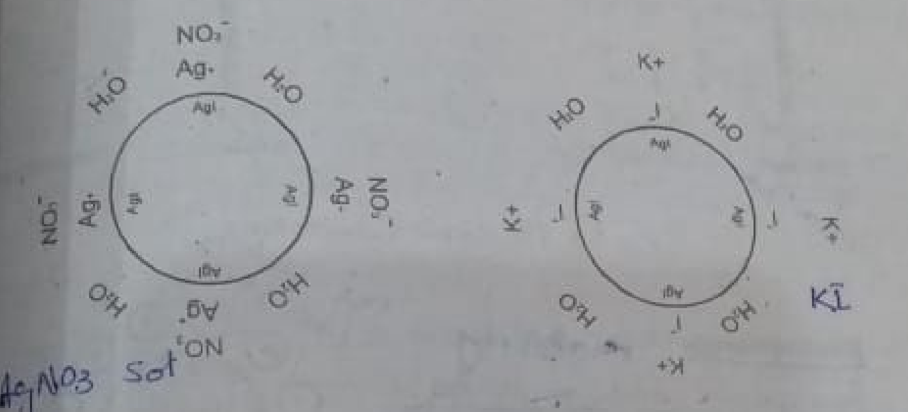

Fig. 8.7. *Silver iodide sols stabilised by (a) iodide ions (b) silver ions.*

...trical Double Layer and Zeta Potential

A charged colloidal particle is surrounded by ions of opposite kind. The ions of ...type (+ve or −ve) get adsorbed and thus form a fixed charged layer on the colloidal ...icle. Figure 8.8 depicts the formation of (a) −ve and (b) +ve fixed layer at the solid-...id interface. Ions of opposite charge from the liquid phase tend to approach this layer ...rder to neutralize the charge. Due to thermal agitations in the liquid phase, however, ...e ions cannot remain fixed to form a parallel plate. They, therefore, get statistically ...ributed forming what is called the diffused or mobile layer in such a way that its net ...rge is equal and opposite to that on the fixed layer. The two taken together is a *double* ...*er system*. Since separation of charge is a seat of potential, the charges of opposite ...ns on the fixed and diffused parts of the double layer result in the appearance of a ...ference of potential between these layers. This potential difference between the fixed ...arged layer and the diffused layer having opposite charge is termed the *electrokinetic* ...*ential* or *zeta potential*. The electrical double layer theory proposed by Helmholtz and ...ended by Guey, Stern and others provides plausible explanation for many electrical ...perties of the colloidal system.

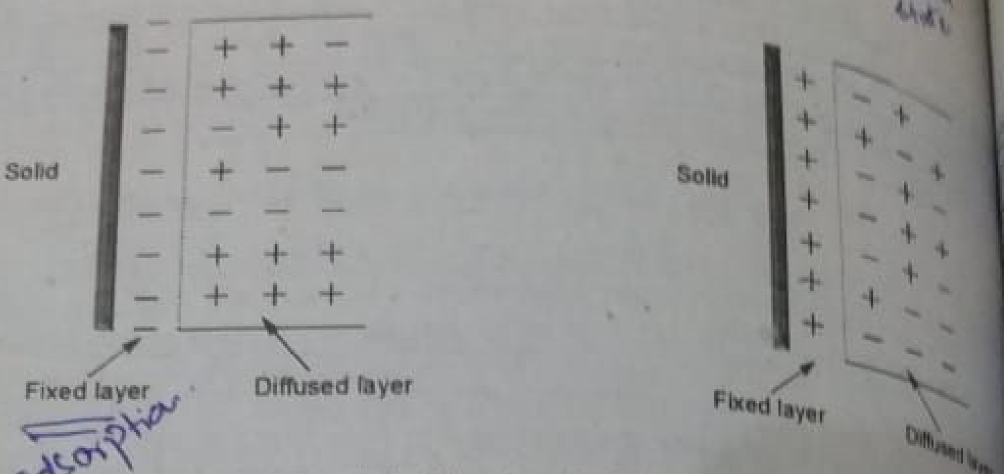

Fig. 8.8. The electrical double layer.

8. Electrophoresis

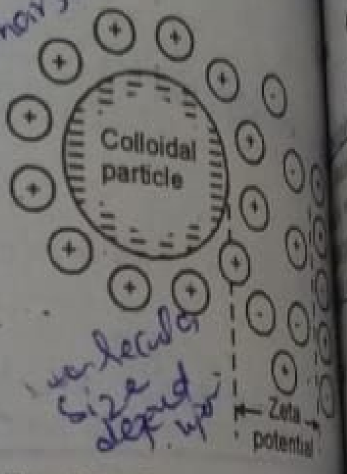

Fig. 8.9. Origin of Zeta potential

Since colloidal particles are charged and when placed in an electric field, these particles migrate either towards the cathode or anode depending upon their charges. This phenomenon of migration of colloidal particles in an electric field is called *electrophoresis* or *cataphoresis*. The speed of colloidal particles when the applied field strength is 1 volt cm^{-1} is known as electrophoretic mobility. The electrophoretic mobility depends upon the molecular size of the colloidal particle. The difference in the electrophoretic mobilities is used in the separation of mixtures. The apparatus used for electrophoresis is shown in Fig. 8.10. It consists of a U-tube containing a hydrosol (medium, e.g., ferric hydroxide sol and water in which tl connected to a source of suitable E.M.F. On applying a between the colloid and water begins to move towards the falls gradually on the positive electrode and rise simultaneo side. Conversely, if the solution particles are negatively ch: potential gradient is known from the applied E.M.F. and Hence the velocity of the particles under a potential of 1 Electrophoresis can also be utilized for quantitative measur of sol particles.

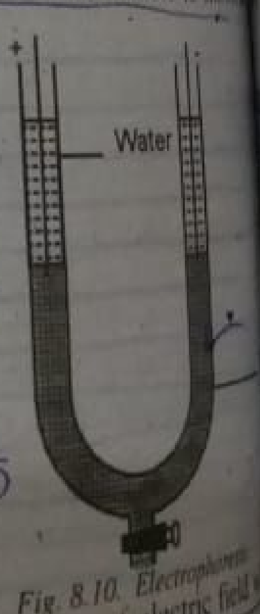

Fig. 8.10. Electrophoresis ... *electric field*

9. Electro-osmosis

The movement of dispersion medium under the influence of electric field when the dispersed particles are prevented from moving is known as *electro-osmosis*.

In electrophoresis, the particles move but the dispersion medium remains ... In electro-osmosis the opposite occurs; the liquid moves through a porous ... under the influence of an applied electric ... Apparatus shown in Fig. 8.11 is used for ... demonstrating the phenomenon of electro-osmosis ... laboratory. In this D and D′ are diaphragms ... divide the apparatus into three compartments. The middle compartment is filled ... sol while the side compartments are filled ... two electrodes and are filled with pure water.

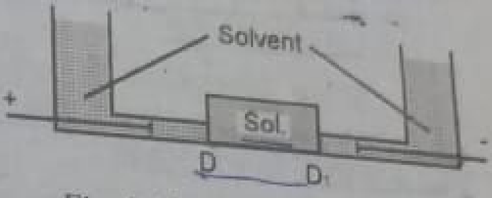

Fig. 8.11. Electro-osmosis.

... an electric field is applied across the two electrodes, the water is observed to move ... one or the other electrode depending on the charge of the sol. This phenomenon ... electro-osmosis is used technically in the removal of water from peat, in dewatering ... clay and in drying dye pastes.

COAGULATION OF COLLOIDS

Coagulation is the process of breaking up of a colloidal solution resulting in the ... aggregation of the particles of the dispersed phase. The stability of a colloidal solution ... mainly due to charge on the particles of the sol. Removal of charge in hydrophobic ... would lead to coagulation of sols, while to coagulate hydrophilic sol, both the ... charge and salvation must be removed. Compared to the *hydrophilic sols, hydrophobic* ... are readily precipitated. This may be achieved in following different ways.

By Electrophoresis

In electrophoresis, the particles of the dispersed phase move towards the ... oppositely charged electrodes. If the process is allowed to continue for a definite period ... the these particles touch the electrode, loss their charge and get coagulated.

By Mutual Precipitation

When two oppositely charged sols (e.g., $Fe(OH)_3$ and As_2S_3 sols) are mixed in ... equal proportions, their charges neutralize each other and the dispersed phases of ... the sols coagulate and settle down. This is termed as mutual precipitation.

By the Addition of Electrolytes

Traces of electrolytes are essential for the stability of a sol, while the addition of ... relatively large amounts of electrolytes make the sol unstable. The colloidal ... particles grow in size and are precipitated out. This phenomenon of precipitation or ... coagulation of the sol particles is known as *flocculation* and was observed by T. Graham ... The amounts of electrolytes required to precipitate a given sol depend on the ... nature of both the sol and the electrolyte. For a given sol, the precipitation power of an ... electrolyte is determined by two factors, namely,

...and Electrical Properties

The individual particles of an aerosol ordinarily are not visible, but a cloud will ... apparent by the obscuration of light. The scattering of light by transparent ... is directly proportional to the sixth power of radius and inversely proportional ... fourth power of wavelength. Because blue light is scattered more readily than red ... smokes often appear blue in colour.

Ordinarily, aerosols are not charged electrically. Under some conditions, clouds ... charged by induction in the atmosphere, and as a result of coagulation, the ... builds up to a high potential, giving rise to the phenomenon of lightning.

Aerosols are of great importance in our daily life. Many pharmaceutical ...arations are used as fine solid particles or liquid mist for respiratory system or nasal ...age. Also, aerosols are of great value for cosmetic industry such as perfumes, ...mpoos, shaving creams etc. are marketed in aerosol packages. Further applications of ...osol research are in the production of smoke screens, fire fighting fogs and the control ... dust explosions.

8.12. APPLICATIONS OF COLLOIDS

There are a number of important processes in which colloids play an important role.

(a) Leather tanning is a process which utilizes colloidal properties. Raw hides contain giant molecules arranged in long tangled fibers. Tanning materials which include tannin and compounds of chromium and aluminium are in colloidal state and the positively charged protein fibers adsorb negative charges from these metallic ingredients. Tanning imparts hardness to leather and prevents it from putrefaction.

(b) A very useful application is in Cottrell precipitation, as purification process for industrial smoke. The air near the factories and industrial plants is frequently contaminated with smoke and gases which result from the manufacturing processes. The smoke is laden with colloidal particles, such as cement dust, arsenic compounds and metallic powder which are irritating and even poisonous. The Cottrell precipitator (Fig. 8.16) removes colloidal particles from the flue gases by means of electrical precipitation. In the Cottrell precipitator, flue gases are passed over wires maintained at high voltage where suspended particles acquire an electric charge. A collecting plate of opposite charge attracts the charged particles which lose their charge and fall to the bottom. The air pollution is thus reduced to a minimum.

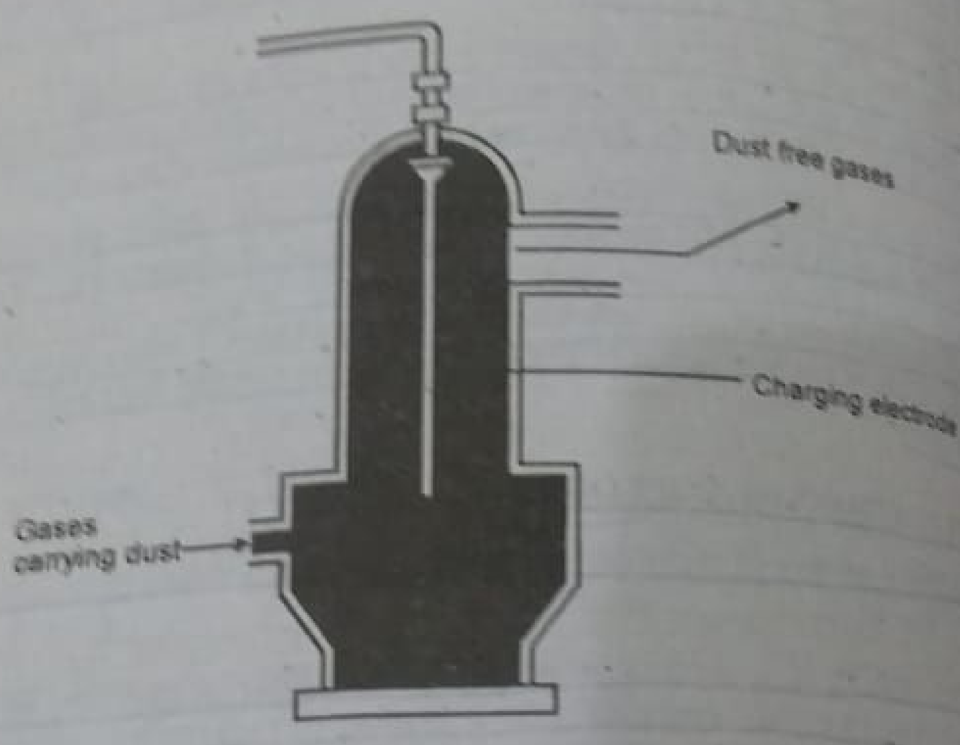

Fig. 8.16. *Cottrell precipitator*

(c) In textile dyeing, colloidal substances called mordants are used to fasten dyes.

(d) In purification of water, aluminium sulphate and lime are added to form flocculent precipitate of aluminium hydroxide. This precipitate will adsorb the fine particles of clay or other suspended matter and carry them to the settling tank. The reaction can be symbolised as

$$Al_2(SO_4)_3 + 3Ca(OH)_2 = 2Al(OH)_3\downarrow + 3CaSO_4$$

Extensive deposits of silt or clay formed at the mouth of rivers by colloidal action are called *deltas*.

(e) Smoke screens consist of titanium dioxide particles dispersed in air and are used in warfare for the purpose of concealment.

(f) "Fire-foam" is a carbon dioxide froth made by mixing solution of sodium bicarbonate and alum. A protective colloid such as glue, dextrin or saponin is added to stabilize the foam and keep the bubbles in finely dispersed form.

The disposal of sewage water by passing it into a tank fitted with metallic electrodes at high voltage. The suspended particles which are charged, move towards oppositely charged electrodes get discharged and are precipitated out.

In drilling deep well or tube-wells, a colloidal solution is used to prevent the rock chips cut by the drill from forming a compact mass.

Colloids are of great importance in living systems. For example, protoplasm itself is a gel. It contains considerable amount of protein, glycogen and phospholipids; all are lyophilic materials. Molecules of these substances exhibit imbibtion, that is they attract water strongly and so firmly that the water is said to be bound. When the particles in colloids rearrange and force some of the bound water out, syneresis is said to occur. It has been suggested that the efficiency of certain substances used in pharmaceutical preparations may be increased if colloidal forms are used, since these have large surface areas.

Blood plasma substitutes are colloidal dispersions in which the particle size is such that they are retained in the blood vessels for an adequate time. Colloidal gold, calcium and silver are used in medicines or as ointments.

The cleansing action of detergents is due to its emulsifying properties. They form an emulsion with oil and dirt particles in water, which is carried away by moving water.

Colloids also find numerous applications in agriculture. For example, the fertility of soil depends on the relative amount of colloids in the soil. The humus and clay are the important ingredients of soil. If the ratio of these components is greater in the soil, then it will hold water and plant nutrients in a better way.