BS (4 Years) for Affiliated Colleges

Code	Subject Title		Cr. Hrs	Semester
CHEM-403	**Physical Chemistry (Sp. Theory-I)**		**4**	**VII**
Year	Discipline			
4	**Chemistry**			

SYLLABUS OUTLINE:

1. Colloids and Surfactants:
Colloids, Colloidal dispersions, sols and their preparation, properties of suspensions, Optional properties of sols, determination of particle size, kinetic properties of sols, sedimention of suspensions. electrical properties of sols, electrophoresis and electro osmosis, stability of suspensoids, precipitation of sols, associated colloids, macromolecular properties in solutions and molecular weight determinations.

Chapter 9

COLLOIDS

CHAPTER 9

COLLOIDS

9.1 INTRODUCTION

The water soluble substances like **sodium chloride, copper sulphate** and sugar dissolve in it and a homogeneous solution (سولیوشن جس میں ایک جیسا پن ہو) is obtained. The particles of these solutes are not visible. The sizes of particles are just equal to their molecule or ions. Such solutions or mixtures are called **true solutions.**

However, when we take muddy river water (کیچڑ والا دریائی پانی) or insoluble substances like lead sulphate, calcium sulphate etc. in water then the particles of the solutes are visible even with the naked eye (کھلی آنکھ سے). The reason being that their sizes are large. On keeping for some time, particles settle down. Such mixtures are called **suspensions.**

Now, between these two extremes, there are particles which are bigger than molecules but are too small to be seen even by a microscope. Such solutions are called **colloidal solutions** simply as sols. The colloidal state can thus be regarded as the intermediate stage between molecules and particles of a coarse suspension.

In 1861, **Thomas Graham** noted that the **crystalline substances** (قلموں کی شکل میں چیزیں) like sugar, glucose, urea and sodium chloride when dissolved in water can pass through a **semipermeable membrane** (وہ جھلی جو کسی محلول کے کچھ اجزاء کو چھانے اور باقی کو نہ چھانے). He also observed that the particles of **glue** (گوند), **gelatin** (جانوروں کی ہڈیوں سے حاصل شدہ چپکانے والا مادہ) and gum arabic do not pass through the semipermeable membrane. He called the first substance as crystalloid (قلمی) and the other substances as **colloid** (گوند نما). This word is derived from the word "Kolla" means '**glue**' and 'eidos' means 'like'. Actually this difference is due to the sizes of the particles.

Shapes Of Colloidal Particles:

The colloidal particles may be **rod like, disc like, thin films or long filaments. We can say that a system whose one dimension length, width or thickness lies in the range of 10 – 200 A° is called colloidal dispersion.**

Born	21 December 1805, Glasgow, Scotland
Nationality	Scottish
Fields	Chemistry
Institutions	Royal College of Science and Technology, University College London
Known for	Graham's Law, Dialysis
Died	16 September 1869 (aged 63)

Thomas Graham

The distinguishing characters of the three types of solutions are given in Table (9.1)

Table (9.1): Difference Between a True Solution, Colloidal Solution and Suspension.

True Solution	Colloidal Solution	Suspension
1 (i) The molecules of solute are not visible, even with a powerful microscope.	(i) The molecules of the dispersed phase cannot be seen with naked eye, but they can be made visible through ultramicroscope.	(i) The particles of suspension are so big that they are visible even with naked eye. They can settle down when the mixture is allowed to stand.
(ii) The diameters of particles are below 1mm.	(ii) The diameters lie in range 1 – 100 nm.	(ii) The diameters lie above 100 nm.
2 (iii) It is a homogeneous mixture.	(iii) It is a heterogeneous mixture.	(iii) It is completely a heterogeneous mixture.
(iv) The particles of the solute can pass through a parchment (پرچی) membrane.	(iv) The particles can not pass through a parchment membrane.	(iv) The particles can not pass through the parchment membrane.
3 (v) The solute molecules can pass through even fine filter papers.	(v) The colloidal particles can also pass through ordinary filter papers, but can not pass through filter papers called ultrafilters.	(v) The suspended particles are retained even by ordinary filter papers.
(vi) The osmotic pressure exerted by the solution is relatively more.	(vi) They exert a very low osmotic pressure.	(vi) There is no osmotic pressure of suspensions.
(vii) The path of light is not illuminated when a strong beam of light is thrown on a true solution.	(vii) When a strong beam of light is passed through a colloidal solution, the path of light is visible due to scattering (بکھرنا) of light. This is called **Tyndall effect**.	(vii) No Tyndall effect is observed in suspensions.
4 (viii) The true solutions do not possess the property of **adsorption** (سطح پر جذب ہونا).	(viii) Colloidal solutions posses remarkable property of adsorption.	(viii) The phenomenon of adsorption is not prominent.

Q: Differ. suspension and gel
precipitation

(ix) The electrical properties as electroosmosis, cataphoresis and coagulation are not observed.	(ix) Colloidal solutions give these electrical properties to a great extent (کافی حد تک).	(ix) Such electrical properties are not given.

9.1.1 Phases in a Colloidal Solution

As discussed above, a colloidal solution is a heterogeneous system. It is consisted of two phases i.e., the dispersed phase (وہ فیز جو بکھر جائے) and the **dispersion medium** (وہ فیز جس میں بکھراہٹ ہو).

(a) **Dispersed Phase:**
The component which is present in **smaller proportion** (کم نسبت والا) is the dispersed phase. In a colloidal solution of starch in water, starch is the dispersed phase.

(b) **Dispersion Medium:**
The component which is present in **greater proportion** is dispersion medium. Colloidal solution of starch in water, has water as the dispersion medium.

These definitions convince (قائل کرنا) us that particles of dispersed phase i.e., colloidal particles are bigger than those of dispersion medium.

9.2 CLASSIFICATION OF COLLOIDS

Imp

Colloids can be classified on the basis of following aspects.

(i) Physical state of dispersed phase and dispersion medium
(ii) Appearance (دکھاوا)
(iii) Solvent affinity

The following discussion will elaborate these aspects.

9.2.1 Classification of Colloids on the Basis of Physical State of Dispersed Phase and Dispersion Medium

Just like true solution, this classification is based on three states of matter. Each of the dispersed phase and the dispersion medium can be a solid, liquid or gas. There are eight different possible combinations. Table (9.2) describes the various colloids in which the dispersed phase and dispersion medium may have the same or different physical states (طبعی حالتیں).

Solute Solvent

Table (9.2): Classification of Colloids Based on Physical State of the Phases.

S. No.	Dispersed Phase	Dispersion Medium	Name of Sol	Examples
(i)	Solid	Solid	Solid sol	Alloys, coloured glass, gems.
(ii)	Solid	Liquid	Sol	White of egg, paints, inks, colloidal gold, colloidal platinum.
(iii)	Solid	Gas	Aerosol	Smoke, dust.
(iv)	Liquid	Solid	Gel	Cheese, curds, jelly, pudding.
(v)	Liquid	Liquid	Emulsion	Milk, butter, oil in water.
(vi)	Liquid	Gas	Aerosol	Mist, fog, clouds.
(vii)	Gas	Solid	Solid foam	Bread, cake, pumice stone.
(viii)	Gas	Liquid	Foam	Soap, lather, aerated water.

9.2.2 Classification of Colloids on the Basis of Appearance

There are two main categories in this respect.

(i) **Sols:** → liquid

When a colloidal solution appears as a fluid (بہہ جانے والی) then it is termed as sol. Dispersion medium decides the name. For example when dispersion medium is water, they are called hydrosols. If the dispersion medium is alcohol they are called **alcosols**. Similarly if it is benzene, they are called **benzosols**.

(ii) **Gels:**

When a colloid has a solid like **rigid appearance** (دیکھنے میں سخت ہو) it is called **gel**. The colloidal system in which the dispersed phase is a liquid and dispersion medium is solid is known as gel. A gel is formed by interlocking (باہم جڑے ہونا) of the dispersed phase particles. Gelatin dissolves in warm water to form a colloidal solution which sets into a gel. Some substances may occur both as sols as well as gels. This depends upon the relative concentrations (باہمی ارتکاز) of the dispersed phase and dispersion medium. E.g: Jelly, Pudding

9.2.3 Classification of Colloidal Solutions on the Basis of Solvent Affinity

There are again two main categories in this respect.

(i) Lyophilic sol (انتشار پذیر)
(ii) Lyopholic sol (غیر انتشار پذیر)

When the dispersion medium exerts an attraction on the dispersed phase then we get **lyophilic sol** which means **solvent loving** (سالونٹ سے محبت کرنے والا). When the attraction between the dispersion medium and the dispersed phase is very little then the sol is called **lyophobic sol** which means **solving hating**. Metals, sulphur, sulphides, silver halides, egg albumen, silicic acid and ferric hydroxide give non-reversible colloidal systems with water. They are also called non-reversible sols and are lyophobic sols.

Protein, starch, glue, gelatin and agar-agar give reversible colloidal system with water. Rubber in benzene is also a reversible colloidal system. They are also called reversible sols and are lyophilic. The main points of difference between lyophilic and lyophobic sols are given in Table (9.3). The solvent is considered as water in this comparison.

Table (9.3): Difference Between Lyophilic and Lyosphobic Sols (Colloids)

Lyophilic Colloids	Lyophobic Colloids
(i) Lyophilic colloids pass into the colloidal form readily when brought in contact with solvent.	(i) Lyophobic colloids do not form the colloidal solutions easily when treated with solvent.
(ii) Such colloids are called the reversible sols.	(ii) They are called irreversible sols.
(iii) They can be recovered from the colloidal solutions and can be converted into the colloidal form when desired.	(iii) They can not be recovered from their colloidal form.
(iv) Only large quantities of electrolytes cause precipitation.	(5) Particles migrate only in one direction in the presence of electric field.

The particles are not easily detected in the ultra-microscope.	(v) The particles are easily detected by an ultramicroscope.
The particles may or may not migrate in an electric field. The migration may be in any direction.	(vi) Even small quantities of the electrolytes can cause precipitation.
Substances like starch, proteins, gums, soaps, and metasilicic acid are common examples of lyophilic sols.	(vii) Colloids of metals (Au, Pt), sulphur, assenius sulphide and silver iodide are common examples of lyophobic sols.

9.2.4 Important Features Of Lyophilic And Lyophobic Sols:

(i) Lyophilic sols can be obtained easily by mixing certain materials like starch or protein with suitable solvents. Lyophobic sols can not be prepared so easily.

(ii) Hydrophilic sols may have little or no charge at all while the particles of hydrophobic sols carry positive or negative charge.

(iii) There happens solvation of the colloidal particles in hydrophilic sols, but not in hydrophobic.

(iv) The viscosity (گاڑھا پن) of lyophilic soles are usually greater than the pure dispersion medium. But in the case of hydrophobic sols the viscosities do not change.

(v) Lyophilic sols can be precipitated only by high concentration of electrolytes, but lyophobic sols are precipitated with low concentration.

(vi) Lyophilic sols are reversible but lyophobic are irreversible.

(vii) Lyophilic sols do not give Tyndall effect, but lyophobic sols do give.

(viii) When electrical field is applied, then lyophilic sols show little tendency (کم رجحان) to move towards the electrodes, but lyophobic sols show greater tendency to do so.

9.2.5 Dispersion Colloids, Multimolecular or Association Colloids, Macro-molecular or Molecular Colloids

Dispersion Colloids:

Those colloids solutions in which the dispersed phase has little affinity (کم رجحان رکھنا) for the dispersion medium are called dispersion colloids. In this case the solid substance is insoluble in the dispersion medium. The sizes of the solid particles lie in the colloidal range. Generally this type belongs to lyophobic sols. For example, **gold** sol, **hydrated ferric** oxide sol, **colloidal sulphur**, a colloidal dispersion of As_2O_3 in water etc are included in this category.

Association Colloids Multi-molecular:

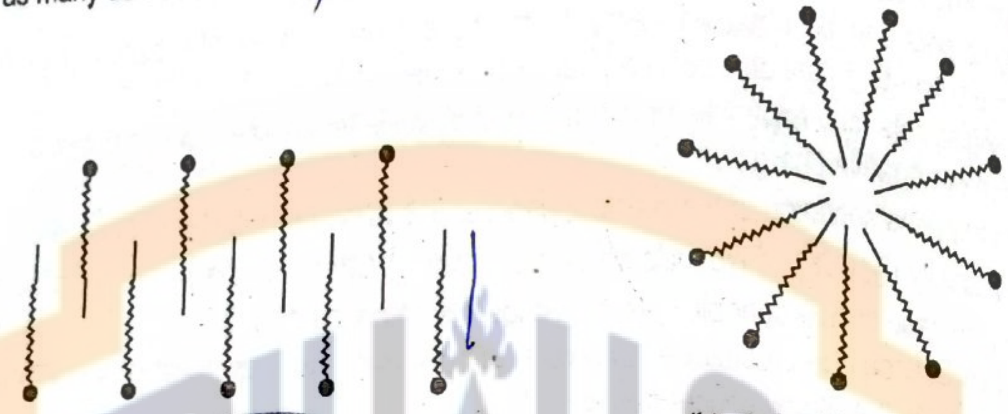
In these colloids the colloidal particles consists of an aggregate (مجموعہ) of a large number of small atoms or molecules. The size of such species lies in the colloidal range. Generally in this type, there is occurrence of lyophobic and lyophilic portions in the same molecules. For example, **soap solution, dyes, surface active agents** etc. Thus the aggregates of ions or molecules with lyophilic as well as lyophobic parts are called micelles (مسونتی محلول میں سالموں کا جم گھٹا). However, the individual ions or molecules may not be of the colloidal dimensions.

Molecular Colloids or Macromolecular:

In macromolecular colloids each particle of the dispersed phase is of colloidal dimensions. Mostly this type consists of lyophilic sols. This resembles true solutions in some respects. **Proteins, cellulose**, the **solutions of rubber** and **high polymers in organic solvents** are a few examples.

9.3 MICELLES

Micelles are colloidal solutions. There are certain strong electrolytes which give a normal solution at low concentration and show colloidal nature at higher concentrations. These are solutions of colloidal nature and are called **micelles**. These substances are also to be referred to as **associated colloids**. Soap forms micelle. These substance are commonly named as **surface active substances**. They have as lyophilic as well as lyophobic parts in the same molecule. A long hydrocarbon chain serves lyophobic and an ionic group like carboxy or sulphonic serves as lyophilic. A micelle may contains as many as 100 molecules. Fig. (9.1)



(a) Lamellar micelle (b) Spherical micelle

Fig. (9.1) Micelle formation (They actually exist in three dimensions)

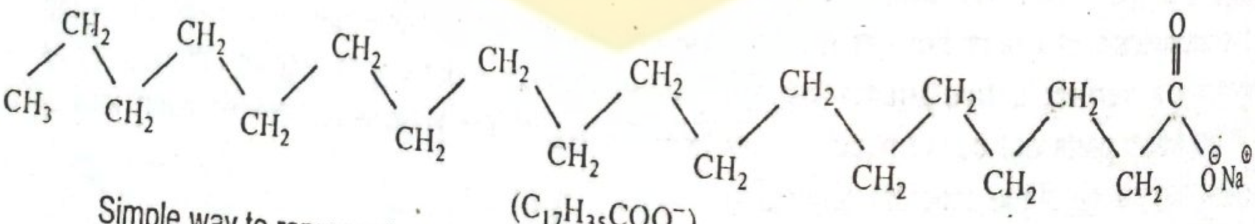
Detergents are similar to soap and so form the micelles.

9.3.1 Cleansing Action of Soaps on the Basis of Micelle Formation

High surface tension of water makes it not a good medium for cleaning our body or clothes. It does not spread evenly over the dirt particularly grease in the clothes or on the body. Without complete wetting of grease by water, we can not expect efficient cleaning. The function of soap or other synthetic detergents is to decrease the surface tension of water. This is made possible by micelle formation as shown in Fig. (9.2)

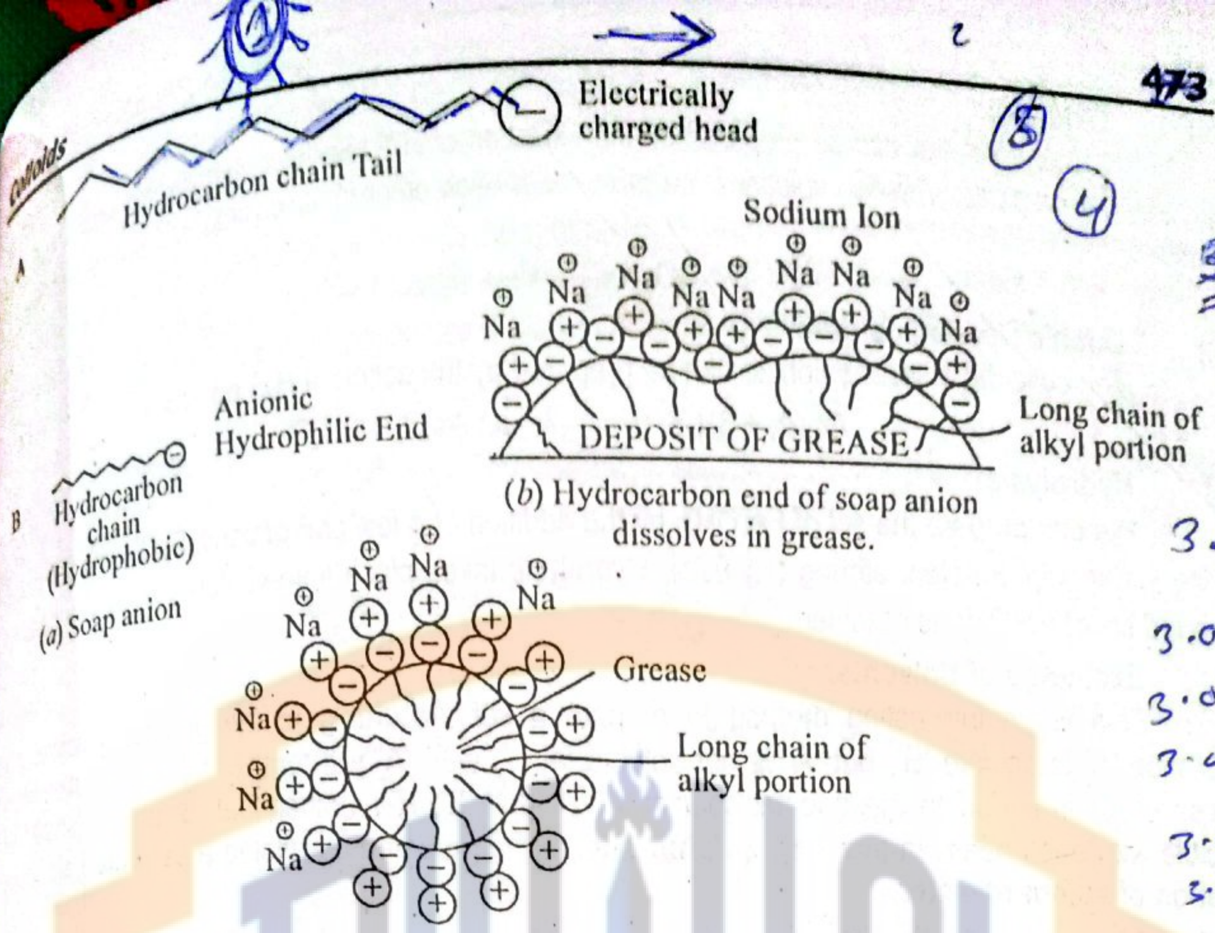
Soap is a sodium or potassium salt of long chain carboxylic acids. Ordinary soap is sodium stearate $C_{17}H_{35}COONa$. When dissolved in water it gives $C_{17}H_{35}COO^-$ in solution. The hydrocarbon chain consisting of 17 carbon atoms is hydrophobic (پانی سے دور رہنے والی) in nature. A number of such hydrocarbon chains are directed towards grease. The negative poles of the stearate ions then attract the positive ends of water forming a **micelle**, Fig. (9.2)

The molecule of a soap is as follows.



$(C_{17}H_{35}COO^-)$

Simple way to represent soap anion.



(c) Grease micelle is formed

Fig. (9.2) (A) Representation of a soap molecule, (B) Formation of a micelle.

3.4
3.9
3.1
3.0
3.01
3.02
3.03
3.04

Then excess water is provided to the piece of cloth. The micelles are then washed away with more water. The function of soap is to reduce grease or oil to colloidal particle, therefore, soaps are emulsifying agents. Grease particles are prevented from coming closer because of the covering by soap molecules. A synthetic detergent like sodium lauryl sulphate $C_{17}H_{25}SO_4^{\ominus}Na^{\oplus}$ would form a miscelle by a similar mechanism.

$C_{17}H_{25}SO_4^- Na^+$

9.4 PREPARATION OF SOLS

Lyophilic sols, for example, soaps, **detergents** (مُصفّا کار), geltin (مچھی سریش), gum arabic (ببول کا گوند), and starch (نشاستہ) can be prepared by simply dissolving these substances in water.

Lyophobic sols are prepared by two types of methods:

(i) Condensation methods
(ii) Dispersion methods.

9.4.1 Condensation (سالموں کا قریب آنا) Methods:

In these methods, the ions and molecules which are originally present in the true solutions are converted to insoluble particles of colloidal dimensions by means of chemical reactions.

These methods are as follows:

(i) **Reduction:**

With the help of this technique (ہُنر), we prepare the colloidal solutions of metals. Preparation of **colloidal gold or silver** by the reduction of the dilute solution of a salt of the metal is done with the help of a organic reducing agent.

Gold chloride can be reduced with **tannin** (نامیاتی مرکب جو بعض درختوں کی چھال سے حاصل ہوتا ہے). **Silver** sol is prepared by reduction of silver carbonate with **tannic acid.**

(ii) Oxidation:

Colloidal sulphur can be prepared by the oxidation of H_2S. For this purpose, the solutions of H_2S and SO_2 are prepared. The two solutions are mixed with each other in stoichiometric (ترتیب و مساوات بتاتی ہے) amounts.

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

(iii) Double Decomposition:

The colloidal arsenic sulphide can be prepared by the action of H_2S on As_2O_3.

$$As_2O_3 + 3H_2S \longrightarrow As_2S_3 + 3H_2O$$

(iv) Hydrolysis:

We can prepare the sol of $Fe(OH)_3$ by the addition of a few cm^3 of conc. $FeCl_3$ with 500 cm^3 of boiling water with constant stirring (متواتر ہلانا). Hydrolysis takes place immediately (فوراً) and a beautiful deep red sol of $Fe(OH)_3$ is obtained.

(v) Exchange of Solvents:

This is an interesting method to prepare a sol. According to the general principle, if a substance 'A' is soluble 'B', but 'A' is not soluble in 'C', then 'A' will form a colloidal solution when excess of 'C' is added to the original solution of 'A' and 'B'. Remember that 'B' and 'C' should be miscible with each other. In this way, **sulphur sol** can be prepared by adding a **saturated alcoholic solution of sulhur to water.**

9.4.2 Dispersion Methods:

In these methods, the material in the bulk is dispersed in another medium. We will discuss three methods in this respect.

(i) Mechanical dispersion
(ii) Bredig's arc method
(iii) Peptization

(i) Mechanical Dispersion (میکانکی بکھراہٹ):

A coarse (رف) suspension of the substance is prepared in the dispersion medium and is passed through the colloidal mill. The mill is consisted of two steel plates which rotate at very high speed i.e. 7000 rotation per minute in opposite directions (مخالف سمتوں میں).

The particles of the coarse suspension pass through these plates and they face powerful shearing (قینچی کی طرح کاٹتی ہوئی) force. In this way, the particles are broken and a sol is prepared. Colloidal graphite, which is a lubricant and the printing inks can be prepared by this method. Following Fig. (9.3) makes the idea clear

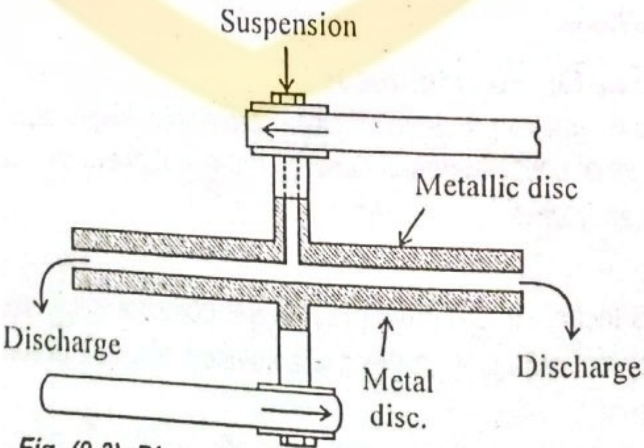


Fig. (9.3) Disc mill to prepare a colloidal solution.

(ii) Bredig's Arc Method:

This is a sort of electrodispersion (برقی طریقہ سے بکھیرنے والا), and the hydrosols of the metals like Ag, Au and Pt can be prepared. Two metal electrodes are held close together beneath (نیچے) water. The temperature of water is kept very low and a small amount of KOH is added. An electric spark (تیز برقی رو) is given. Intense heat of spark between the electrodes vapourises some metal and these vapour condense under water. These atoms of the metal present in the vapour aggregate (اکٹھا) to form the colloidal particles. Following Fig. (9.4) makes the idea clear.

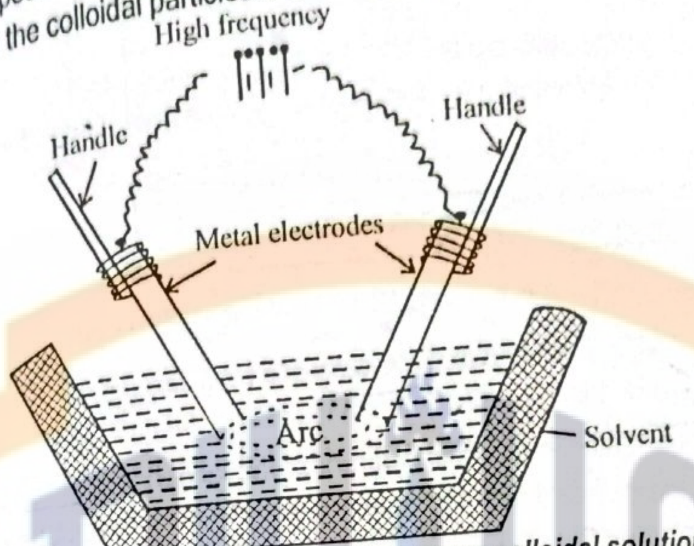


Fig. (9.4) Bredig's arc method to prepare colloidal solution.

(iii) Peptization:

Peptization is the reverse process of coagulation (اکٹھا کرنے کا عمل). It is a direct disintegration (بکھر جانے کا عمل) or dispersion of a substance into particles of colloidal size by using peptizing agent.

Most of the hydrophilic substances such as **glue, gum** and **gelatin** are peptized by water. Water acts as a peptizing agents. AgCl can be converted into sol by adding HCl. Similarly, $Fe(OH)_3$ can give a sol by adding Fe^{+3} ion.

9.4.3 Purification Of Sols:

Whenever the sols are prepared, then some ionic or molecular substances are also present. In order to purify the sols, these electrolytes have to be removed. Mostly following three methods for this purpose are employed.

(i) Dialysis (باریک چادر سے چھان کر اجزاء کا جدا کرنا)

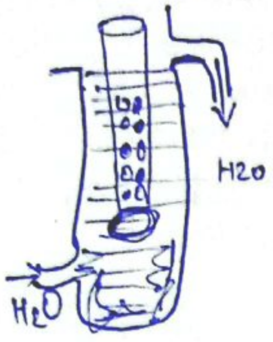
(ii) Electrodialysis (برقی رو سے الگ کرنا)

(iii) Ultrafilteration (بہت ہی نفیس قسم کی فلٹریشن)

(i) Dialysis:

As we have stated earlier that the particles of the two solutions can pass through the membrane but colloidal particles are retained (بچ جانا). Colloidal particles diffuse (نفوذ کرنا) very slowly due to their large sizes. The important membrane used for this purpose may be **parchment paper** (کھال کا بنا ہوا کاغذ), **cellophane** (باریک شفیف لپٹنے والا کاغذ), **cellulose nitrate** and cellulose acetate.

The arrangement is consisted of cylindrical vessel (سلنڈر کی طرح کا برتن) whose one end is covered with the membrane and other is open for the addition of colloidal solution. This cylindrical vessel along with the colloidal solution is placed in a large dish, containing distilled water. The supply of the distilled water is continued. Following Fig. (9.5) shows this arrangement. The particles of the true solution go to the large dish in distilled water.



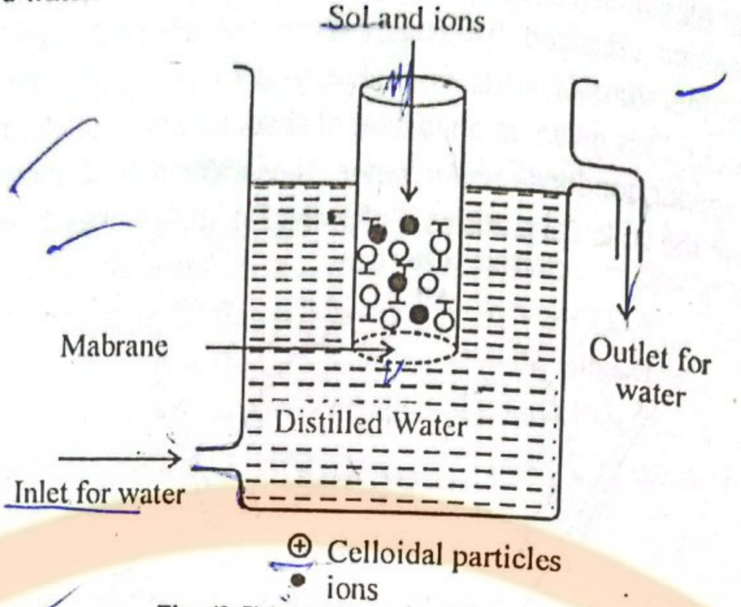


Fig. (9.5) Working of a Dialyser.

(ii) **Electrodialysis:**

In this method, the dialysis is carried out under the influence of electrical field (برقی میدان). The two ends of the dialyser are covered with the membrane (جھلی). The colloidal solution is placed in drum shaped vessel which is suspended in distilled water. Two electrodes are supplied as shown Fig. (9.6). The ions of the electrolytes move towards the oppositely charged electrodes. In this way, they are taken away by distilled water. Anyhow, the non-electrolytic impurity like urea and sugar are not removed.

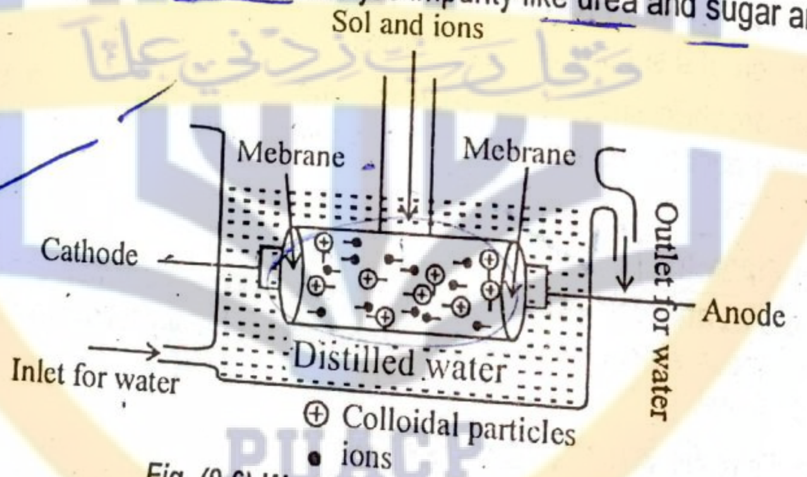


Fig. (9.6) Working of a electrodialyser

(iii) **Ultrafilteration:**

It is a separation of sol particles from the liquid medium and electrolytes by filteration through an ultrafilter.

We know that the sol passes through an ordinary paper due to the big sizes of the pores of the filter paper. But, if the filter paper is impregnated (بھراہوا) with colloid ion or a regenerated (دوبارہ بنایا) cellulose, then the pore sizes of the filter papers are much reduced. This type of modified filter paper (ترمیم شدہ فلٹر پیپر) is called an ultrafilter. Ultrafiteration is a slow process. If we use the graded ultrafilters, then the technique of ultrafilteration can be supplied to separate the sol particles of different sizes.

2.5 PROPERTIES OF SOLS (COLLOIDAL SOLUTIONS)

Different properties of colloidal solutions are discussed under the following headings:

2.5.1 Colour

Colour of a sol depends on the wavelength of the light scattered by the dispersed phase. The wavelength further depends upon the size and nature of the particles. The colours of silver sol are as follows.

Colour of Silver Sol	Particle Size (mm)
Orange-yellow	6×10^{-5}
Orange-red	9×10^{-5}
Purple	13×10^{-5}
Violet	15×10^{-5}

2.5.2 Tyndall Cone Effect:

This is one of the optical (نوری) properties of sols. When a strong beam of light is passed through a sol and viewed at right angles, then the path of light shows up in the form of hazzy (دھندلا سا) beam or cone. The reason is that the sol particles absorb the light energy and the emit it in all directions in space. This is the scattering (بکھرنا) of light. It illuminates (روشن کرنا) the path of the beam.

If the particles are of colloidal size, then we do not see the particles themselves. **The path of light through the colloid which is made visible as a result of light scattering, is called the Tyndall beam or Faraday Tyndall cone.** This light scattering depend upon three factors.

(i) **Wavelength of the light used**

(ii) Difference in the **refractive index** between the particles and the surrounding medium.

(iii) Size and **configuration** (باہمی ترتیب) of the particles.

- True solutions donot show the Tyndall effect. However, this effect can be observed when the light has to pass through the solutions of particles of very small size having a thick layer of molecules. Diagram (9.7) shows Tyndall cone effect.

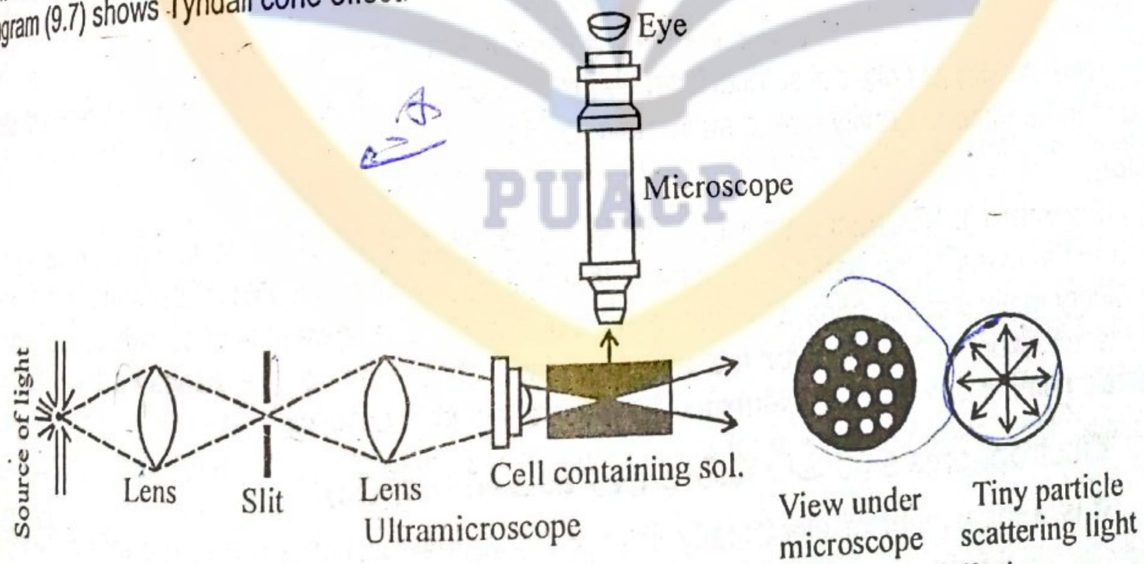


Fig. (9.7) The diagram of the slit ultramicroscope and Tyndall cone effect.

Applications Of Tyndall Cone Effect:

The blue of the sky and the red of the sunset is a sort of Tyndall cone effect. Actually, the small sized particles of oxygen and nitrogen scatter the shorter wavelength more effectively (منتشر ہونا) than longer wavelengths. If there were no scattering, the light would reach us only by direct transmission from the sun or by reflection from the surfaces. Hence, the sky would appear as dark in day time as at night, and the sun would act as a huge spot of light during the day.

Do You Know That!

It is this effect which is made use of in the 'test box' in testing the purity of SO_2 for the manufacture of sulphuric acid by the Contact process.

9.5.3 Mechanical Properties (Brownian Movement)

The particles of a colloidal solution are in a constant rapid zig-zag (ادھر اُدھر بے ترتیب) motion. This **zig-zag motion is called Brownian movement.** Robert Brown first noticed this movement while examining pollen grains suspended in water under a microscope.

Now, ultra-microscope can be used for this purpose. This motion is due to **unequal bombardment** by the molecules of dispersion medium. When the size of particles increases the probability of unequal bombardment decreases. **Brownian movement decreases with increase of particle size** Fig. (9.8).

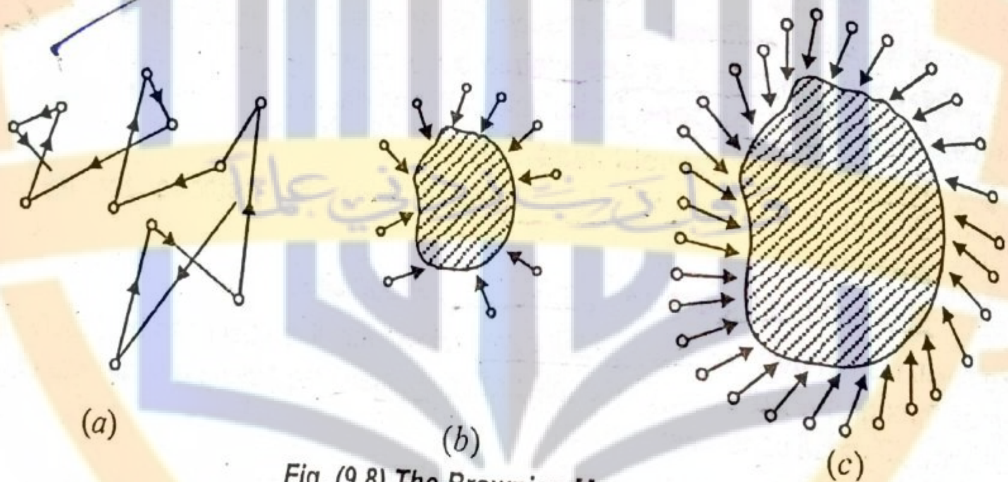


Fig. (9.8) The Brownian Movement.

The stability of colloidal solution can be justified due to these forces. The particles do not settle down under the force of gravity due to such movements.

Diffusion:

According to Graham's Law of diffusion. The rates of diffusion decrease very rapidly with increase in the mass of the particles. It means that colloidal solutions would diffuse much more slowly than ordinary molecular solutions. One can determine the molecular weights of colloids by this method. Since the equation to be used for the purpose also has a term for the Avogadro's number. The Avogadro's number can also be determined from this concept of diffusion.

9.5.4 Electrophoresis (برق انتقالی، برقی قوت سے کسی مائع کے ذرات کا حرکت کرنا):

It is a movement of electrically charged colloidal particles under the influence (اثر) of applied electrical field.

In order to study the electrophoretic effect, we consider the following arrangement Fig. (9.9). It is a U-shaped tube fitted with a stop cock for drainage (باہر نکلنا). The funnel shaped filling tube is attached. First of all some quantity of distilled water is placed in a tube. Then the sol is introduced through the funnel. In this way, water is displaced upwards. Sharp boundaries are produced in the two arms. Electrodes are introduced in the two side arms and connected to a source of potential (طاقت). If the colloidal particles are positively charged, the level of the sol falls gradually (آہستہ سے) on the anode side, and rises on cathode side.

During the process of electrophensis, the sol particles reach the respective electrodes and after getting discharged, they are precipitated. The phenomenon of electrophosis is explained in the Fig. (9.9).

The phenomenon of electrophoresis can be used to determine the sign of the charge on the colloidal particles. We can also measure the rate of traveling of colloidal particles. Since, different colloidal species in a mixture travel at different rates, so separation can be performed by this method. ***So electrophoresis is used extensively for the fractionation (حصے کرنے کا عمل) and analysis (تجزیہ) of proteins, nucleic acids, polysacchrides and other complex substances of biological interests.***

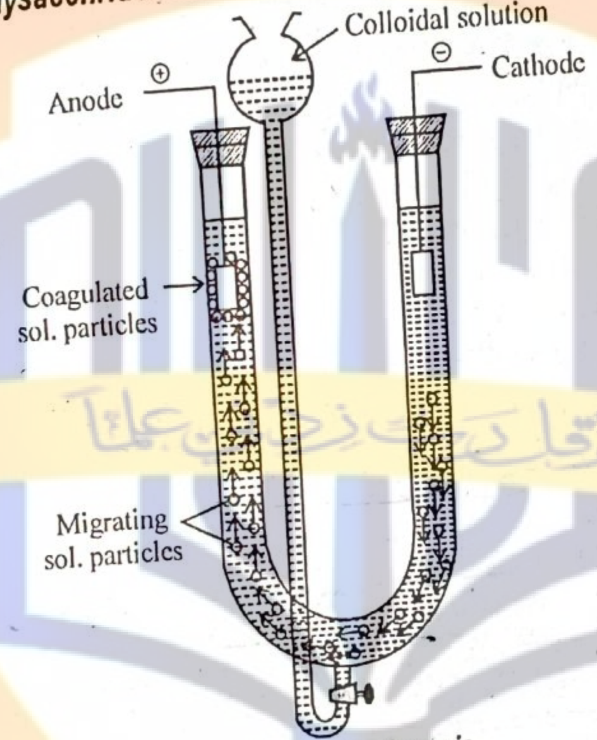


Fig. (9.9) Electrophoresis

9.5.5 Electro-osmosis

This process is just the reverse of electrophoresis. **In this process, the liquid moves through a fixed porous material.**

Following arrangement Fig. (9.10) can help us to understand the process. A U-shaped tube is fitted with a porous (سوراخ دار) material 'M'. This porous material may be wool or a porous clay (سوراخوں والی مٹی) diaphragm. The electrical current is set up across the electrode. The dispersion medium moves towards the other electrode. This phenomenon of electro-osmosis is used technically (ہنر مندی سے) in the removal of water from moist clay (گیلی مٹی) and for drying the pastes. Look at following diagram (9.10) to understand it.

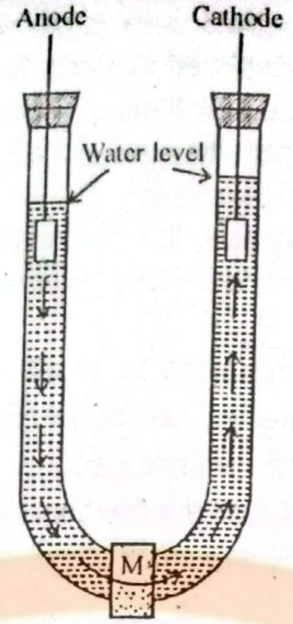


Fig. (9.10) Arrangement for electro-osmosis.

9.5.6 Streaming Potential:

The phenomenon of streaming potential can be studied from the same above mentioned diagram for electro-osmosis Fig. (9.10). In this arrangement the electrodes of the apparatus are not connected to the battery but to a galvanometer. Initially, there will be no current. But if water is forced through the tube, than electromotive force (EMF) is indicated in a galvanometer. It can be noted very easily that the potential (طاقت) which is produced is proportional to the pressure (دباؤ). The potential so developed is called **streaming potential**.

9.5.7 Sedimentation (نیچے بیٹھنا) Potential Or Dorn effect:

The word sedimentation means settling down. This phenomenon can be observed, if the particles are forced to move in a resting (ساکن) liquid. This can be done by gravitational force (کشش ثقل). The potential so produced is known as sedimentation potential. This is also called "Dorn effect".

This process is just the reverse of electrophoresis.

9.6 STABILITY OF COLLOIDAL SOLUTIONS

The stability of colloidal solution is due to the charge on particles. The particles carry either positive or negative charge. Since all the colloidal particles bear identical charge, they repel each other and do not precipitate easily under the effect of gravity. The electrophosis helps us to determine the charge on particles.

Table (9.4): Charge on the Colloidal Particles

Positively Charged		Negatively Charged	
(i)	Basic dye stuffs.	(i)	Clay
(ii)	Colloidal particles of Fe $(OH)_3$, $Cr(OH)_3$ and $Al(OH)_3$.	(ii)	Metallic particles like those of gold, silver and platinum.
(iii)	Haemoglobin.	(iii)	Sulphides of Cu, Pb, As, Sb and Cd.
		(iv)	Silicic acid, stannic acid and vanadium pentoxide.
		(v)	Gum-Arabic and soluble starch.
		(vi)	Acid dye stuffs.

9.6.1 Origin of Charge on Colloidal Particles

The presence of electric charge on the sol particles is by one or more of the following reasons.

(i) **Friction:**

It may be due to rubbing of the particles of dispersed phase against those of dispersion medium.

(ii) **Selective Adsorption:**

Sometimes the sol particles have a tendency to adsorb anions or cations from the solution. Take the example, of colloidal particles of As_2S_3. They can adsorb either As^{3+} or S^{2-} ions. Since during the precipitation of this sol, only sulphide ions from H_2S are in excess, therefore on a colloidal particle of As_2S_3, the S^{-2} ions get adsorbed and the particles become negatively charged.

In the same way the sol of $Fe(OH)_3$ obtained by the hydrolysis of $FeCl_3$ is positively charged. Actually in the medium, there are present particles of $Fe(OH)_3$, Fe^{3+} and Cl^- ions. Fe^{3+} ions get adsorbed on the surface of $Fe(OH)_3$ and particles become positively charged.

AgCl is insoluble substance in water. The AgCl particles can adsorb Cl^- ions from solution containing Ag^+ ions. The colloidal particles become negatively charged in the first case and positively charged in the second case.

(iii) **Electron Capture:**

During electro-dispersion of the metals in Bredig's arc method electron being used in electrical circuit are picked up (اُٹھایا جانا) by colloidal particles.

(iv) **Dissociation of Surface Molecules:**

Soap molecules dissociate (ٹوٹ جانا) to give ions. The cations pass into solution whereas the anions ($C_nH_{2n+1}COO^-$) aggregate (اکٹھا ہونا) together to form a negatively charged big particles called micelle.

(v) **Presence of Acid or Basic Group:**

Protein molecules yield colloidal solutions. Since a protein molecule contains an acidic group -COOH and also a basic group $-NH_2$, it will give a positive colloidal particle in acidic medium and a negative particle in alkaline medium.

In Acid:

$$H_2N - X - COOH + HCl \longrightarrow H_3^+N - X - COOH + Cl^-$$

In Alkali:

$$H_2N - X - COOH + NaOH \longrightarrow H_2N - XCOO^- + Na^+ + H_2O$$

9.6.2 Theory of Electrical Double Layer

Let us consider the solid-liquid interface (جہاں ٹھوس اور مائع کی سطحیں ملتی ہیں). This is the layer at the point of junction (ملاپ) of solid colloidal particles and the molecules of dispersion medium. There exists an electrical double layer (دوہری تہہ) of opposite charges at the surface of separation between a solid and a liquid.

Actually when a solid is in contact with a liquid, double layer of ions appears at the surface of separation. One part of the double layer is fixed on the surface of the solid. This is known as the fixed part of the double layer. It consists of either positive ions or negative ions. The second part consists of a diffuse or a mobile layer of ions which extends into the liquid phase. This layer consists of ions of both the signs but its net charge is equal and opposite to that on the fixed part of the double layer. Such arrangement of charges is shown in Fig. (9.11). In one case Fig. (9.11) the fixed part of the double layer carries positive charge while in the second case Fig. (9.11), the fixed part carries negative charge.

The above phenomenon is applicable to colloidal systems as well. The ions which are preferentially (ترجیحی بنیادوں پر) adsorbed by the colloidal particles, are held in the fixed part of the double layer. These ions give the characteristic charge to the colloidal particles. The oppositely charged ions which are set free in dispersion medium are arranged by layer of solvent molecules at the junction (ملاپ والی جگہ). These ions are present more in the diffuse portion of the double layer and gives a net opposite charge to this layer.

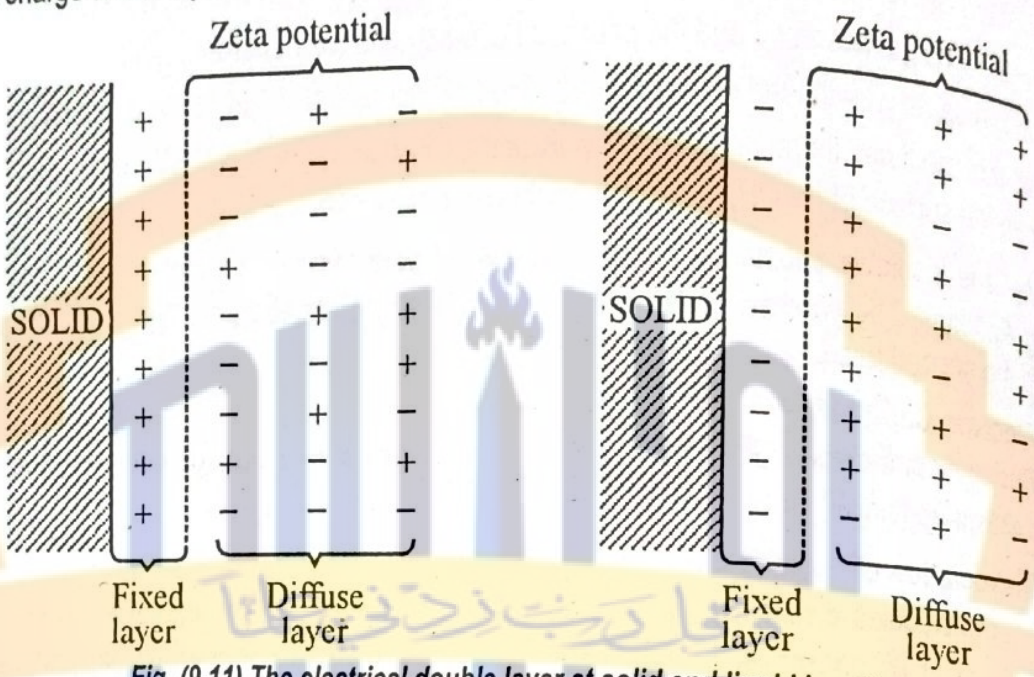


Fig. (9.11) The electrical double layer at solid and liquid junction.

Development of Potential Difference

The existence (وجود ہونا) of charges of opposite signs on the fixed and diffuse parts of the double layer leads to the appearance (ظاہر ہونے کی صفت) of **a difference of potential between the two layers.** This difference of potential between the two layers is known as **zeta potential** or **electro-kinetic potential**.

9.6.3 Coagulation X

Coagulation is a process in which the charge over colloidal particles is neturalised and results in the precipitation of the colloidal particles. For this process we do the addition of an electrolyte (برق پاشیدہ). For example, when **barium chloride** solution is added to **arsenic sulphide sol**, it becomes turbid. After sometimes a precipitate of arsenius sulphide settles down. The charge on the colloidal particles is neutralised. We know that arsenius sulphide is a negatively charged sol. The sol of As_2S_3 is stable due to mutual (باہمی) repulsion between the various colloidal particles having similar charge. After the addition of $BaCl_2$ solution the negative charge on the colloidal particles is neutralised by the positive charge on barium ions. Thus the colloidal particles accumulate to form particles of larger size and coagulation results Fig. (9.12).

Flocculation:

If the coagulated substance floats then it is called flocculation.

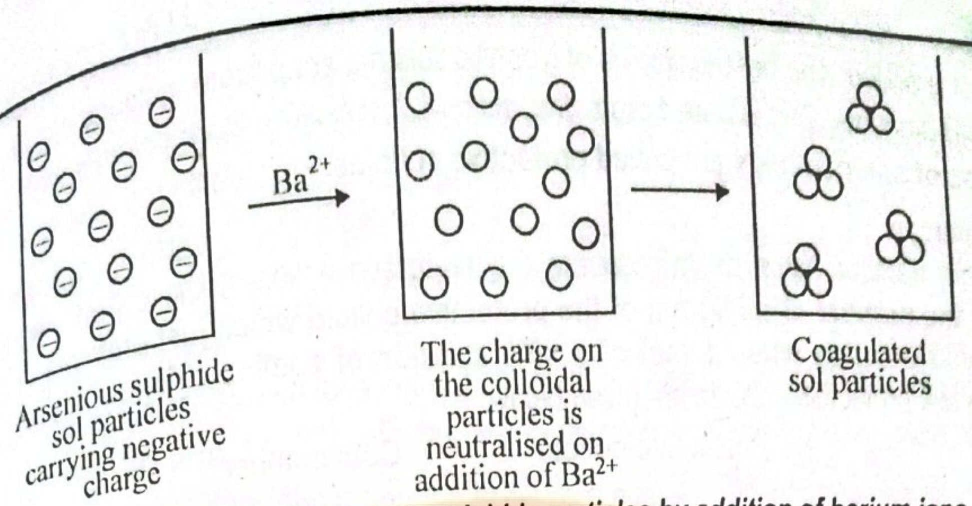


Fig. (9.12) Coagulation of arrenious sulphide particles by addition of barium ions.

9.6.4 Hardy-Schulze Rule

As discussed above that oppositely charged ions from the electrolyte are used up to effect coagulation. **The power of an ion to effect coagulation depends upon its valency**. According to Hardy-Schulze Rule, higher is the valency of an active ion, greater will be its power to coagulate colloidal solution. For example, for the coagulation of negatively charged aresenious sulphide (As_2S_3) sol, trivalent cations (Al^{3+}) are much more effective (زیادہ اثر والی) than bivalent (Ba^{2+}) or monovalent (Na^+) cation.

On similar grounds for the coagulation of positively charged ferric hydroxide sols, trivalent anions (PO_4^{3-}) are more effective than divalent (SO_4^{2-}) or monovalent (Cl^-) anions.

9.6.5 Flocculation Value

The minimum concentration (کم سے کم ارتکاز) **of an electrolyte in millimoles that must be added to one litre of a colloidal solution so as to bring about complete coagulation or flocculation is called the flocculation value.**

There is another way to get coagulation. This can be done by mixing two oppositely charged colloidal solutions. For example, by mixing ferric hydroxide $Fe(OH)_3$ sol with arsenious sulphide (As_2S_3) sol, coagulation takes place.

Let us have three electrolytes as

$$Na_3PO_4,\ MgCl_2,\ Al_2(SO_4)_3$$

For a negative sol, greater the charge on the cation, greater the flocculation value. The charges on the cation in the given electrolytes are as follows:

Electrolyte	Cation	Charge
Na_3PO_4	Na^+	+1
$MgCl_2$	Mg^{2+}	+2
$Al_2(SO_4)_3$	Al^{3+}	+3

Hence the flocculation value of the electrolytes will be in the order

$$Al_2(SO_4)_3 > MgCl_2 > Na_3PO_4$$

9.6.6 Protective Colloids and Gold Number

Protective Colloids:

As discussed earlier that lyophobic colloids are sensitive (زود اثر). They are likely to coagulate (اکٹھا ہو کر جانا) in the presence of electrolytes. However, they can be stabilized if a small amount of a lyophilic sol is added. The best examples of lyophilic sols are **soap, gum, gelatine** etc. They are added in very small amounts. This is called protective action (حفاظت والا عمل). **Such colloids which prevent the coagulation of other colloids are called protective colloids.**

Gold Number:

Gold number helps us to measure the protective action of the colloid. Gold number is **defined as the number of milligram of the protective colloid which just prevents coagulation of 10 ml of gold solution when 1 mol of a 10% solution of sodium chloride is added to it.** Gold number of a few protective colloids are given below:

Protective colloid	Gold number
Gelatin	0.005
Albumin	0.08
Starch	25

Calculation of Gold Number:

Suppose the coagulation of 100 ml of a colloidal solution of gold is completed by addition of 0.25 g of starch to it after adding 1 ml of 10% NaCl solution. The gold number of starch for such a solution will be calculated as follows.

100 ml of colloidal solution requires to prevent coagulation is **0.25** g starch or 250 mg starch.

10 ml of colloided solution requires to prevent coagulation 25 mg starch.

So, gold number of starch is 25.

Let us consider that the gold numbers of four substances as A, B, C and D are 0.005, 0.05, 0.5 and 5 respectively, then which of these has the greatest protective action? The answer is A.

A has the greatest protective action as it requires the minimum quantity of A to prevent the coagulation of the gold solution after the addition of sodium chloride solution.

9.7 MACROMOLECULES

There are certain substances which are themselves composed of giant (بہت بڑے) molecules and dissolve in a solvent to give colloidal solution directly. Such **giant molecules** are called macromolecules. The dimensions of the macromolecule lie in the range of **10 – 1000 A°**. The best examples are **gelatin, synthetic polymer, synthetic rubbers, cellulose** and **starch**. The solutions of macromolecules behave like reversible colloids and are lyophilic in nature. They have high viscosities (تہوں میں رگڑ کی موجودگی) and show a weak Tyndall effect. Anyhow, they do not carry an electrical charge and do not show electrophoresis.

9.7.1 Emulsion (خمیرا):

Those colloidal solutions in which the dispersed phase as well as the dispersion medium are liquids are known as emulsions.

Depending upon the fact that which type of liquid is dispersion phase and the other is dispersion medium, there are two types of emulsions.

(i) Oil in Water Emulsion:

Those emulsions in which oil is a dispersed (بکھرا ہوا) phase, and water is a dispersion medium (جس میں بکھرا ہے). Milk is one of the best examples in which liquid fat is dispersed in water.

(ii) Water in oil emulsion:

Those emulsions in which water is the dispersed phase and oil is the dispersion medium. Butter and cod liver oil are such emulsions.

9.7.2 Emulsification (شیرا بننے کا عمل):

The process of producing an emulsion is called emulsification.

Preparation of Emulsion:

Two immiscible liquids are shaken together e.g., if we shake oil or benzene with water the oily liquid can be dispersed in droplets (چھوٹے ذرّے) but emulsion is not stable. The droplets quickly recombine and the two liquids separate into two layers. In order to stabilize (استحکام بخشنا) the emulsion, an emulsifying agent is added.

Emulsifying agent helps the formation of droplets by lowering the interfacial tension (دو مائعات کے ملاپ والی جگہ پر کھچاؤ). It prevents (روکتی ہے) them from coagulating (اکٹھا ہونے سے). The function of emulsifiers is to act as a protective layer (حفاظتی تہہ) around the oil droplets of emulsion. In this way, its stability increases.

Stomach

Most commonly used emulsifying agents are **soaps** and **detergents.** Some other stabilizing agents are **proteins** and **gums.** Digestion of fats in the intestines is facilitated by emulsification. A small amount of fat forms Na-soap with the alkaline solution of intestine (آنت). It emulsifies the rest of the fat and makes it easier for the digestive enzymes (وہ انضامز جو نظام ہضم میں مدد دیتے ہیں) to do their work.

Many **lotions, creams** and **ointments** are emulsions of oil in water and of water in oil type. Emulsions find applications in the concentrations of ores as well.

9.7.3 Distinction Between "Oil In Water" And "Water In Oil" Emulsion:

Following two tests are applied to distinguish between two types of emulsions.

1. **Dye Test:**

If the emulsion is heated with the oil soluble dye and emulsion gains the colour of the dye, then it is water in oil emulsion. If the emulsion does not catch the colour of the dye, then it will be oil in water emulsion.

2. **Conductance Method:**

Add a small amount of electrolyte in emulsion. If the conductance (برقی رو کا بہاؤ) increases, the emulsion is "oil in water" type and if there is no appreciable change in conductance, then it is "water in oil" type emulsion.

9.7.4 Structure Of Emulsion Particles:

Emulsion is produced by mixing two **immiscible liquids** and an **emulsifying agent.** The emulsifying agent is 0.5 to 5 %. In order to understand it, let us consider an emulsion in which soap is used as an emulsifier in "oil in water" emulsion. The hydrocarbon part of soap molecule will be attracted by the oil and the polar heads will be directed into water as shown in Fig. (9.13).

In this way, the droplets of oil will be protected from coalescence (آپس میں جڑنے کا عمل) by a protective layer of emulsifier. The droplets whose surfaces are covered with soap molecules are however electrically charged by the ionized carboxylic group of the soap. In this way droplets of oil repel each other before they collide and so the emulsion is stabilized.

9.7.5 Factors For The Stability Of Emulsion:

Stability of emulsion depends on following factors:

(i) Thickness (موٹائی) of the protective film.
(ii) Compactness (پختہ پن) of the protective film.
(iii) Electrical charge on the droplet (چھوٹا قطرہ) or the film.
(iv) Viscosity (گاڑھا پن) of dispersed medium.
(v) Density (کثافتِ اضافی) difference between two liquids.

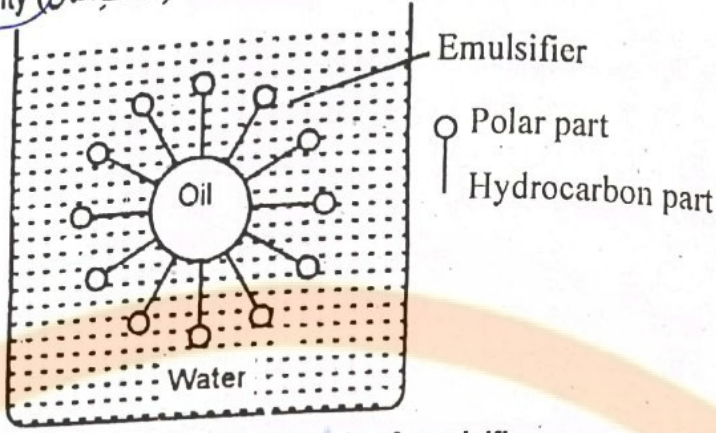


Fig. (9.13) Role of emulsifier

9.7.6 Demulsification:

The process of breaking emulsion to yield the constituent liquids is called demulsification.

Following techniques can be used:

(i) Heating
(ii) Centrifuging (مرکز گریز قوت لگا کر)
(iii) Adding large amount of electrolytes to precipitate out the dispersed phase.

Separation of cream from milk is an example of demulsification by means of centrifugation. / End!

9.8 GELS AND JELLIES

Jellie is a common name for gel and they are semi-rigid sols consisting of two components in which one is a solid and other is a liquid.

Table jellies are prepared from gelatin. Fruit jellies like jams contain the so called pectins (سفید مادہ جو پھلوں کی خلیاتی دیواروں میں پایا جاتا ہے). Pectins are soluble gum like carbohydrates.

9.8.1 Classification Of Gels:

Gels may be classified as:

(i) Elastic (نرم) gels.
(ii) Rigid (سخت) or non-elastic gels.
(iii) Thioxotropic gels.

The best examples of elastic gels are those which are produced from sols of **gelatin, agar, starch, jams, jellies** and many kinds of **puddings.**

Silica gel is a non-elastic gel. Many of the **metallic hydroxides** and **hydrated metal oxides** are non-elastic gels.

Reversible isothermal sol gel transformation is found in certain sols such as colloidal iron oxide and aluminium. If these are allowed to stand undisturbed, then gel formation takes place and if the

...gel is shaken, sol is reformed. This reversible sol gel transformation is known as **thixotropy.** This is very important in paints.

9.9 IMPORTANCE OF COLLOIDS

Many of the substances can exist in colloidal state. All the fields of chemistry are related with colloidal chemistry by one way or the other:

1. All living tissues (خصوصی خلیوں کا مجموعہ جس سے پودوں اور جانوروں کا جسم بنتا ہے) are colloidal in nature so the complex chemical reactions which are necessary to life must be interpreted (جس سے معنی اخذ کیا جائے) in terms of colloidal chemistry.
2. The phenomenon of **adsorption, dialysis** and **coagulation** are important in preparative chemistry and analytical chemistry. For example, co-precipitation, washing of precipitate, filtration and chromatographic analysis are studied in analytical chemistry.
3. Colloidal science is important in manufacture of **paints, plastics, textiles, photographic paper and films, glues, inks, cements, ceramics, rubber, leather, lubricants** (رگڑ کو کم کرنے والے یا چکنا کرنے والے), **soaps** and **synthetic** (مصنوعی) **detergent.**
4. Items like agricultural sprays, insecticides (کیڑے مارنے والی), aerosols, **gels** and **jellies, butter, cheese, salad** and **adhesives** (آپس میں کشش رکھنے والے) involve the colloidal chemistry.
5. Some important processes like **printing**, bleaching (رنگ اڑانا), **decolourizing, tanning, dying** and the separation of **pulverized ores** involve the colloidal chemical aspect. Colloidal chemistry finds important applications to biology and medicine e.g. blood and protoplasm are complex colloidal solutions. Skin, muscles and many different tissues are gels with peculiar structure.
6. The coagulation of colloidal solutions is a very important phenomenon. This fact is applied in nature to a number of technical problems which are as follows.

(i) **Purification of Drinking Water:**

Ordinary water contains suspended (تیرتی ہوئی) impurities. The particles of impurities are of colloidal size, and they don't settle down due to similar charges on them. When potash alum is added, then Al^{+3} ions neutralize the charge on colloidal particle. In this way, they settle down and the water becomes fit for drinking.

(ii) **Medicines:**

Many medicines are being produced in the form of soles. Such medicines are more affective (اثر) because they have greater assimilation (ہضم ہونے کا عمل) and adsorption qualities.

(iii) **Pollution Control:**

Smoke is a colloidal solution of carbon particles in air. Carbon particles can be coagulated by using the conductor near the exist (باہر جانے کا راستہ) of chimney. In this way, carbon particles settle down and the carbonless fumes or air comes out of chimneys. This design is known as Cottrell dust precipitation.

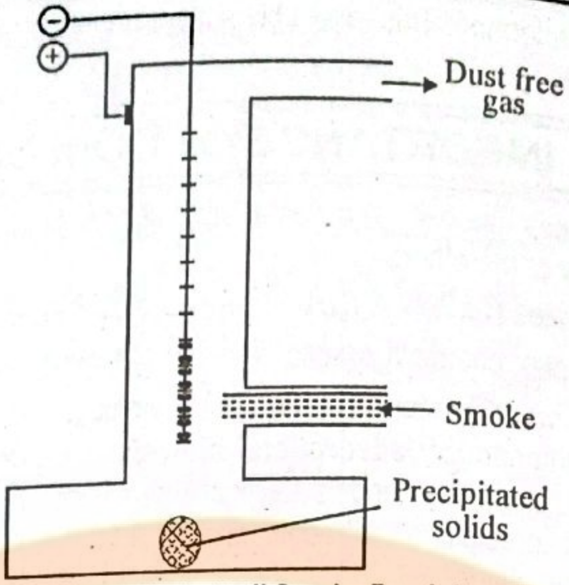


Fig. (9.14) Cottrell Smoke Precipitator.

(iv) Photography:

The photographic film contains the colloidal solution of silver bromide in gelatin. This film can be obtained on a glass plate by depositing a mixture of silver bromide and gelatin.

(v) Sewage Disposal:

The sewage (بدرو کا پانی) disposal carries dirt particles suspended in water. Sewage water is allowed to come in contact with an electrode of opposite charge in a big tank. In this way, dust particles are precipitated and separated. These particles can act as manure (کھاد).

(vi) Tanning:

Both hides (جانوروں کی سوکھی کھالیں) and skins are gel structure containing proteins in the colloidal form. We can tan (زردی آمیز بھورا رنگ) hides to leather by using common salt. Anyhow, in general practice, the precipitation is done by means of alum, chromium salt or by tans from bark of trees (درختوں کی چھال).

(vii) Curd Formation:

When milk sours, then bacteria form lactic acid form milk sugar. This acid changes the colloidal casein into curd.

(viii) Delta Formation:

Delta is formed at a place where the river enters the sea. Actually, sea water is rich in minerals, while river contains **colloidal particles of clay**. When the two waters meet then clay is coagulated. This clay is **fertile (زرخیز) and is known as delta.**

(ix) Natural Rubber:

Natural rubber is obtained from secretion of certain trees as an emulsion of negatively charged particles in water called **latex** (درخت کا دودھ). This latex is changed into rubber by means of dilute acetic acid or by smoke. It is slightly acidic.

(x) Blue Colour of Sky:

Colloidal particles of dust in atmosphere only scatter blue light and absorb rest of the light. Hence blue light reaches us and sky seems to be blue.

(xi) Chemical Warfare:

Smoke and mist (دھندلے پن کے پردے) screens are formed by the explosion of bombs. They are harmful to humans. So we have to wear the gas masks. These masks (نقاب) contain colloidal charcoal, so the dangerous smoke and mist particles are precipitated down and the human life is saved.