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313en08

COLLOIDS

You are familiar with solutions. They play an important role in our life. A large number of substances such as milk, butter, cheese, cream, coloured gems, boot polish, rubber, ink also play an important role in our daily life. They are mixtures of special type. They are colloidal solutions. The term colloid has been derived from two terms, namely colla and oids. 'Kolla' means glue and 'Oids' means like i.e. glue-like. The size of the particles in colloidal solutions is bigger than the size of particles present in solutions of sugar or salt in water but smaller than the size of particles in suspensions. In this lesson you will learn about the methods of preparation, properties and applications of colloidal solutions.



OBJECTIVES

After reading this lesson you will be able to:

- explain the difference between true solution, colloidal solution and suspension;
- identify phases of colloidal solution;
- classify colloidal solutions;
- describe methods of preparation of colloids;
- explain some properties of colloidal solutions;
- explain Hardy Schultz Rule;
- recognise the difference between gel and emulsion;
- cite examples of the application of colloids in daily life; and
- define nano materials and list some of their properties.

8.1 DISTINCTION BETWEEN A TRUE SOLUTION, COLLOIDAL SOLUTION AND SUSPENSION

You may recall that solution of sugar in water is homogeneous but milk is not. When you closely look at milk you can see oil droplets floating in it. Thus, although it appears to be homogenous it is actually heterogenous in nature. The nature of



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the solution formed depends upon the size of the solute particles. If the size of the solute particles is less than 1 nm it will form **true solution** but when the size is between 1 to 100 nm then it will form colloidal solution. When the size of solute particles is greater than 100 nm it will form a suspension. Therefore we may conclude that colloidal solution is an intermediate state between true solution and suspension (Table 8.1).

Table 8.1: Some important properties of true solutions, colloids and suspensions

S.No.	Name of Property	True Solution	Colloids Solution	Suspension
1.	Size	Size of particles is less than 1 nm	Size of particles is between 1nm and 100 nm.	Size of particles is greater than 100 nm.
2.	Filterability	Pass through ordinary filter paper and also through animal membrane.	Pass through ordinary filter paper but not through animal membrane.	Do not pass through filter paper or animal membrane.
3.	Settling	Particles do not settle down on keeping	Particles do not settle down on their own but can be made to settle down by centrifugation.	Particles settle down on their own under gravity.
4.	Visibility	Particles are invisible to the naked eye as well as under a microscope.	Particles are invisible to the naked eye but their scattering effect can be observed with the help of a microscope.	Particles are visible to the naked eye.
5.	Separation	The solute and solvent cannot be separated by ordinary filtration or by ultra filtration.	The solute and solvent cannot be separated by ordinary filtration but can be separated by ultra-filtration.	The solute and solvent can be separated by ordinary filtration.
6.	Diffusion	Diffuse quickly	Diffuse slowly	Do not diffuse

8.2 PHASES OF COLLOIDS SOLUTION

Colloids solutions are heterogenous in nature and always consist of at least two phases : the **dispersed phase** and the **dispersion medium**.

- **Dispersed Phase :** It is the substance present in small proportion and consists of particles of colloids size (1 to 100 nm).

- **Dispersion Medium** : It is the medium in which the colloids particles are dispersed. For example, in a colloidal solution of sulphur in water, sulphur particles constitute the 'dispersed phase' and water is the 'dispersion medium'.

Each of the two phases namely, dispersed phase and dispersion medium can be solid, liquid or gas. Thus, different types of colloidal solutions are possible depending upon the physical state of the two phases. Different types of colloidal solutions and their examples are shown in Table 8.2. You should note that gases cannot form a colloidal solution between themselves, because they form homogenous mixtures.

Table 8.2 : Types of Colloidal Solutions

S.No.	Dispersed Phase	Dispersion Medium	Type of Colloidal Solution	Examples
1.	Solid	Solid	Solid sol.	Gemstones,
2.	Solid	Liquid	Sol	Paints, muddy water, gold sol, starch sol, arsenious sulphide sol.
3.	Solid	Gas	Aerosol of solids	Smoke, dust in air
4.	Liquid	Solid	Gel	Jellies, Cheese
5.	Liquid	Liquid	Emulsion	Milk, Cream
6.	Liquid	Gas	Aerosol	Mist, fog, cloud
7.	Gas	Solid	Solid foam	Foam rubber, pumice stone
8.	Gas	Liquid	Foam	Froth, whipped cream

Out of the various types of colloidal solutions listed above, the most common are **sols** (solid in liquid type), **gels** (liquid in solid type) and **emulsions** (liquid in liquid type). If the dispersion medium is water then the 'sol' is called a **hydrosol**; and if the dispersion medium is alcohol then the 'sol' is called an **alcosol**.



INTEXT QUESTIONS 8.1

1. Classify the following into suspension, colloidal solution and true solution.
milk, sugar in water, clay in water, blood, boot polish, sand in water, face cream, jelly, foam.
2. Give one example each of
(a) Sol (b) Gel (c) Aerosol (d) Emulsion
3. What is the difference between an alcosol and hydrosol?
4. How does colloidal solution differ from true solution.



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8.3 CLASSIFICATION OF COLLOIDS

Colloidal solutions can be classified in different ways :

- (a) on the basis of interaction between the phases.
- (b) on the basis of molecular size.

8.3.1 Classification Based Upon Interaction

Depending upon the interaction between dispersed phase and the dispersion medium colloidal solutions have been classified into two categories.

- (a) **Lyophilic colloids** : The word 'Lyophilic' means solvent lover. Lyophilic colloidal solutions are those in which the dispersed phase have a great affinity (or love) for the dispersion medium. Substances like gum, gelatine, starch etc when mixed with suitable dispersion medium, directly pass into colloidal state and form colloidal solution. Therefore, such solutions are easily formed simply by bringing dispersed phase and dispersion medium in direct contact with each other. However, these colloidal solutions have an important property i.e. they are reversible in nature. This means that once lyophilic colloidal solution has been formed then dispersed phase and dispersion medium can be separated easily. Once separated these can again be formed by remixing the two phases. These sols are quite stable.

If water is used as dispersion medium then it is termed as hydrophilic colloid.

- (b) **Lyophobic Colloids** : The word 'Lyophobic' means solvent hating. Lyophobic colloidal solutions are those in which the dispersed phase has no affinity for the dispersion medium. Metals like Au, Ag and their hydroxides or sulphides etc., when simply mixed with dispersion medium do not pass directly into colloidal state. These sols have to be prepared by special methods. These sols can be readily precipitated and once precipitated they have little tendency to go back into the colloidal state. Thus these sols are irreversible in nature. Also they are not very stable and require a stabilizing agent to remain in the colloidal form. In case water is used as dispersion medium it is called as hydrophobic sol.

8.3.2 Classification Based on Molecular Size

Depending upon the molecular size the colloids have been classified as

- (a) **Macromolecular colloids** – In this type of colloids the size of the particles of the dispersed phase are big enough to fall in the colloidal dimension as discussed earlier (i.e. 1–100 nm)

Examples of naturally occurring macromolecular colloids are starch, cellulose, proteins etc.

- (b) Multi molecular colloids – Here individually the atoms are not of colloidal size but they aggregate to join together forming a molecule of colloidal dimension. For example sulphur sol contains aggregates of S_8 molecules which fall in colloidal dimension.
- (c) Associated colloids – These are substances which behave as normal electrolyte at low concentration but get associated at higher concentration to form miscelle and behave as colloidal solution. Soap is an example. Soap is sodium salt of long chain fatty acid $R\text{COONa}$. When put in water, soap forms RCOO^- and Na^+ . These RCOO^- ions associate themselves around dirt particles as shown below forming a miscelle (Fig. 8.1).

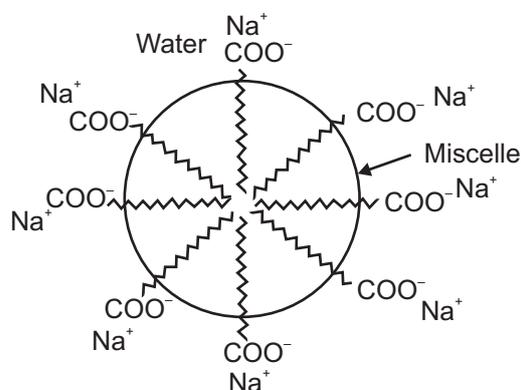


Fig.8.1 : Aggregation of RCOO^- ions to form a micelle.

8.4 PREPARATION OF COLLOIDAL SOLUTIONS

As discussed earlier, the lyophilic sols can be prepared directly by mixing the dispersed phase with the dispersion medium. For example, colloidal solutions of starch, gelatin, gum etc. are prepared by simply dissolving these substances in hot water. Similarly, a colloidal sol of cellulose nitrate is obtained by dissolving it in alcohol. The resulting solution is called **collodion**.

However, lyophobic colloids cannot be prepared by **direct method**.

Hence two types of methods are used for preparing lyophobic colloids. These are:

- (i) Physical methods
- (ii) Chemical methods

(i) Physical methods

These methods are employed for obtaining colloidal solutions of metals like gold, silver, platinum etc. (Fig. 8.2)





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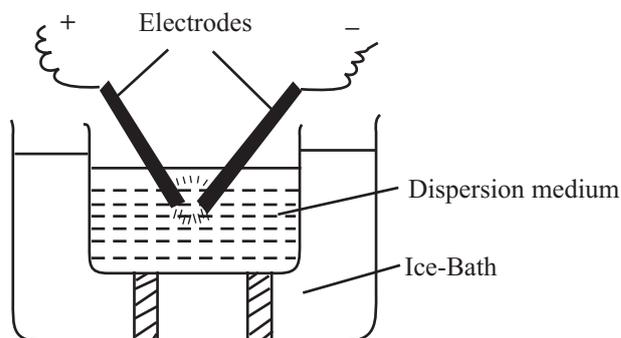


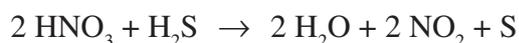
Fig. 8.2 : Preparation of colloidal solution by Bredig's Arc Method

An electric arc is struck between the two metallic electrodes placed in a container of water. The intense heat of the arc converts the metal into vapours, which are condensed immediately in the cold water bath. This results in the formation of particles of colloidal size. We call it as metal sol. e.g. gold sol.

Peptisation : Peptisation is the process of converting a freshly prepared precipitate into colloidal form by the addition of a suitable electrolyte. The electrolyte is called peptising agent. For example when ferric chloride is added to a precipitate of ferric hydroxide, ferric hydroxide gets converted into reddish brown coloured colloidal solution. This is due to preferential adsorption of cations of the electrolyte by the precipitate. When FeCl_3 is added to $\text{Fe}(\text{OH})_3$, Fe^{3+} ions from FeCl_3 are adsorbed by $\text{Fe}(\text{OH})_3$ particles. Thus the $\text{Fe}(\text{OH})_3$ particles acquire + ve charge and they start repelling each other forming a colloidal solution.

(ii) Chemical Methods : By oxidation

Sulphur sol is obtained by bubbling H_2S gas through the solution of an oxidizing agent like HNO_3 or Br_2 water, etc. according to the following equation :



$\text{Fe}(\text{OH})_3$ sol, As_2S_3 sol can also be prepared by chemical methods.

8.5 PURIFICATION OF COLLOIDAL SOLUTION

When a colloidal solution is prepared it contains certain impurities. These impurities are mainly electrolytic in nature and they tend to destabilise the colloidal solutions. Therefore colloidal solutions are purified by the following methods:

- (i) Dialysis
- (ii) Electrodialysis

Dialysis : The process of dialysis is based on the fact that colloidal particles cannot pass through parchment or cellophane membrane while the ions of the

electrolyte can. The colloidal solution is taken in a bag of cellophane which is suspended in a tub full of fresh water. The impurities diffuse out leaving pure colloidal solution in the bag (Fig. 8.3). This process of separating the particles of colloids from impurities by means of diffusion through a suitable membrane is called *dialysis*.

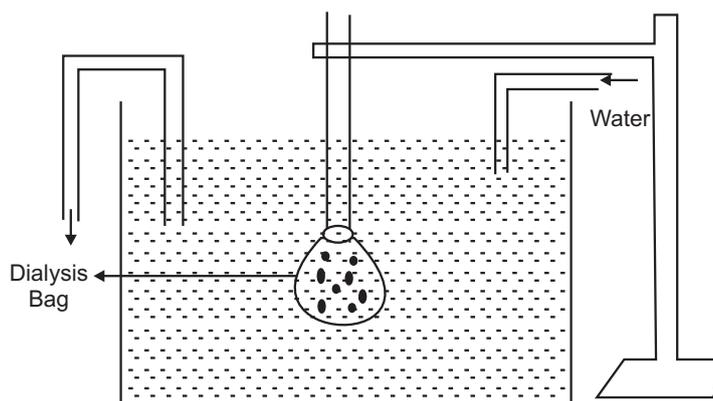


Fig. 8.3 : A dialyser

Electrodialysis : The dialysis process is slow and to speed up its rate, it is carried out in the presence of an electrical field. When the electric field is applied through the electrodes, the ions of the electrolyte present as impurity diffuse towards oppositely charged electrodes at a fast rate. The dialysis carried out in the presence of electric field is known as electro dialysis (Fig. 8.4).

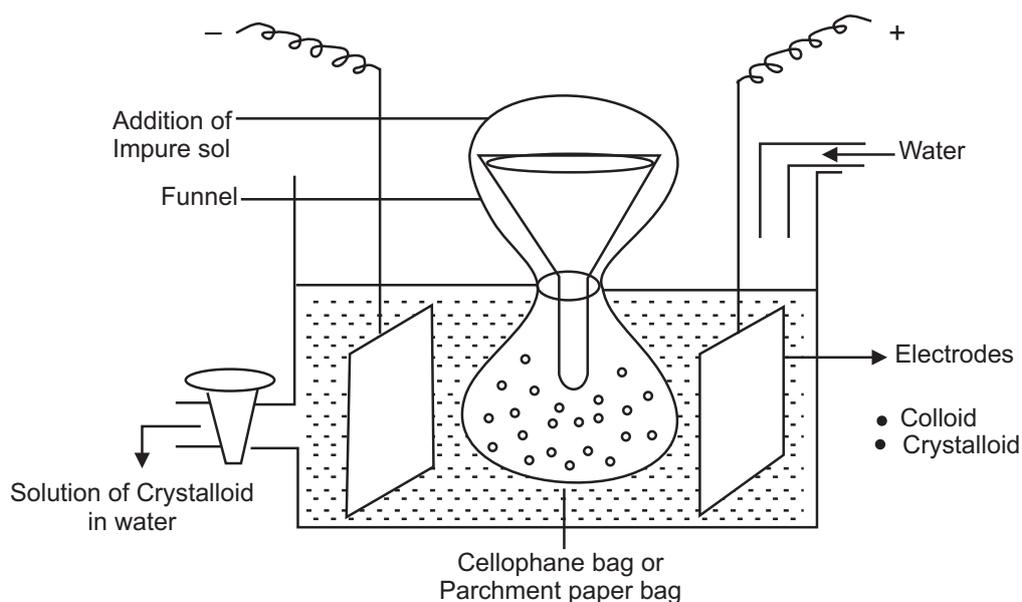


Fig. 8.4 : Electro dialysis



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The most important use of dialysis is the purification of blood in the artificial kidney machine. The dialysis membrane allows the small particles (ions etc.) to pass through, whereas large size particles like haemoglobin do not pass through the membrane.



INTEXT QUESTIONS 8.2

1. Name two colloids that can be prepared by Bredig's Arc method.
2. Name two colloids that can be prepared by chemical methods.
3. Differentiate between (a) Lyophilic and Lyophobic sol. (b) macromolecular and multimolecular colloids.
4. Explain the formation of miscelle.

8.6 PROPERTIES OF COLLOIDS

The properties of colloids are discussed below :

- Heterogeneous character :** Colloidal particles remain within their own boundary surfaces which separates them from the dispersion medium. So a colloidal system is a heterogeneous mixture of two phases. The two phases are dispersed phase and dispersion medium.
- Brownian movement :** It is also termed as Brownian motion and is named after its discoverer Robert Brown (a Botanist.)

Brownian Motion is the zig-zag movement of colloidal particles in continuous and random manner (Fig. 8.5). Brownian motion arises because of the impact of the molecules of the dispersion medium on the particles of dispersed phase. The forces are unequal in different directions. Hence it causes the particles to move in a zig-zag way.

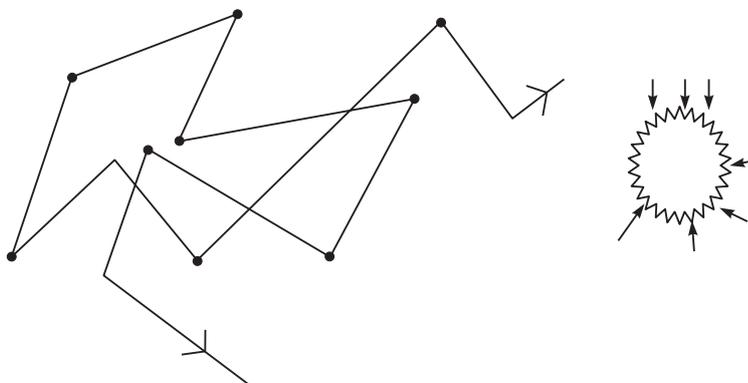


Fig. 8.5 : Brownian Movement

- c) **Tyndall Effect** : Tyndall in 1869, observed that if a strong beam of light is passed through a colloidal solution then the path of light is illuminated. This phenomenon is called Tyndall Effect. This phenomenon is due to scattering of light by colloidal particles (fig.8.6). The same effect is noticed when a beam of light enters a dark room through a slit and becomes visible. This happens due to the scattering of light by particles of dust in the air.

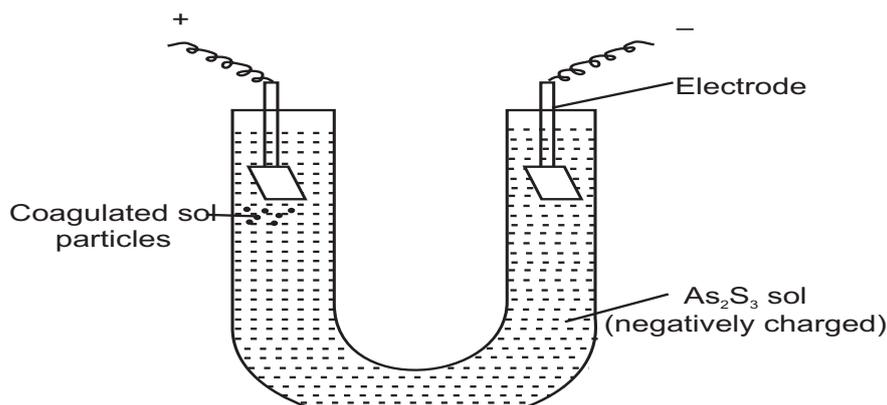


Fig. 8.6 : The Tyndall Effect

- d) **Electrical Properties** : The colloidal particles are electrically charged and carry the same type of charge, either negative or positive. The dispersion medium has an equal and opposite charge. The colloidal particles therefore repel each other and do not cluster together to settle down. For example, arsenious sulphide sol, gold sol, silver sol, etc. contain negatively charged colloidal particles whereas ferric hydroxide, aluminium hydroxide etc. contain positively charged colloidal particles. Origin of charge on colloidal particles is due to:

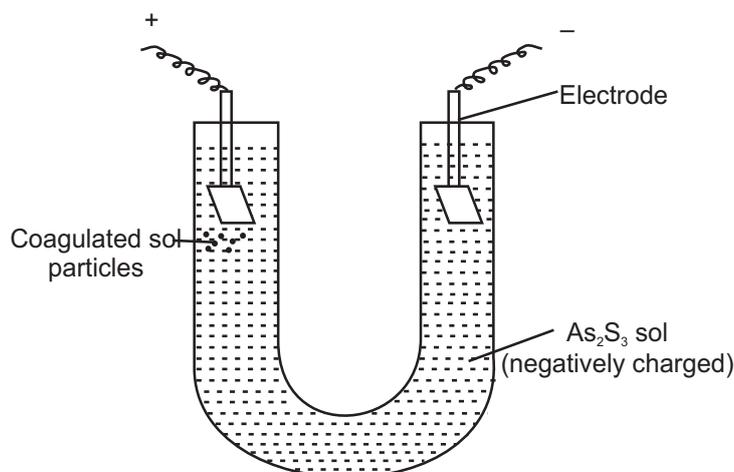


Fig. 8.7 : A set up for Electrophoresis



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- (a) Preferential adsorption of cations or anions by colloidal particles.
- (b) Miscelles carry a charge on them due to dissociation.
- (c) During the formation of colloids especially by Bredig arc method, colloidal particles capture electrons and get charged. The existence of charge on a colloidal particle is shown by a process called **electrophoresis**.

Electrophoresis is a process which involves the movement of colloidal particles either towards cathode or anode under the influence of electrical field. The apparatus used is as shown in Fig 8.7.

8.7 COAGULATION OR PRECIPITATION

The stability of the lyophobic sols is due to the presence of charge on colloidal particles. If, somehow, the charge is removed, the particles will come nearer to each other to form aggregates (or coagulate) and settle down under the force of gravity.

The process of settling of colloidal particles is called coagulation or precipitation of the sol.

The coagulation of the lyophobic sols can be carried out in the following ways:

- (i) *By electrophoresis*: The colloidal particles move towards oppositely charged electrodes, get discharged and precipitated.
- (ii) *By mixing two oppositely charged sols*: Oppositely charged sols when mixed in almost equal proportions, neutralise their charges and get partially or completely precipitated. Mixing of hydrated ferric oxide (+ve sol) and arsenious sulphide (–ve sol) bring them in the precipitated forms. This type of coagulation is called mutual coagulation.
- (iii) *By boiling*: When a sol is boiled, the adsorbed layer is disturbed due to increased collisions with the molecules of dispersion medium. This reduces the charge on the particles and ultimately lead to settling down in the form of a precipitate.
- (iv) *By addition of electrolytes*: When excess of an electrolyte is added, the colloidal particles are precipitated. The reason is that colloids interact with ions carrying charge opposite to that present on themselves. This causes neutralisation leading to their coagulation.

The ion responsible for neutralisation of charge on the particles is called the coagulating ion. A negative ion causes the precipitation of positively charged sol and vice versa.

It has been observed that, generally, the greater the valence of the flocculating ion added, the greater is its power to cause precipitation.

This is known as **Hardy-Schulze rule**. In the coagulation of a negative sol, the flocculating power is in the order:



Similarly, in the coagulation of a positive sol, the flocculating power is in the order:



The minimum concentration of an electrolyte in millimoles per litre required to cause precipitation of a sol in two hours is called coagulating value. The smaller the quantity needed, the higher will be the coagulating power of an ion.

8.7.1 Coagulation of lyophilic sols

There are mainly two factors which are responsible for the stability of lyophilic sols. These factors are the charge and solvation of the colloidal particles. When these two factors are removed, a lyophilic sol can be coagulated. This is done (i) by adding an electrolyte and (ii) by adding a suitable solvent. When solvents such as alcohol and acetone are added to hydrophilic sols, the dehydration of dispersed phase occurs. Under this condition, a small quantity of electrolyte can bring about coagulation.

Protection of colloids

Lyophilic sols are more stable than lyophobic sols. This is due to the fact that lyophilic colloids are extensively solvated, i.e., colloidal particles are covered by a sheath of the liquid in which they are dispersed.

Lyophilic colloids have a unique property of protecting lyophobic colloids. When a lyophilic sol is added to the lyophobic sol, the lyophilic particles form a layer around lyophobic particles and thus protect the latter from electrolytes. Lyophilic colloids used for this purpose are called protective colloids.

8.8 APPLICATIONS OF COLLOIDAL SOLUTIONS

Colloids play a very important role in our daily life. Some of these applications are discussed below:

- (i) **Sewage disposal** : Colloidal particles of dirt, etc. carry electric charge. When sewage is allowed to pass through metallic plates kept at a high potential,



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the colloidal particles move to the oppositely charged electrode and get precipitated there. Hence sewage water is purified.

- (ii) **Purification of Water in Wells :** When alum is added to muddy water, the negatively charged particles of the colloid are neutralized by Al^{3+} ions. Hence the mud particles settle down and the water can be filtered and used.

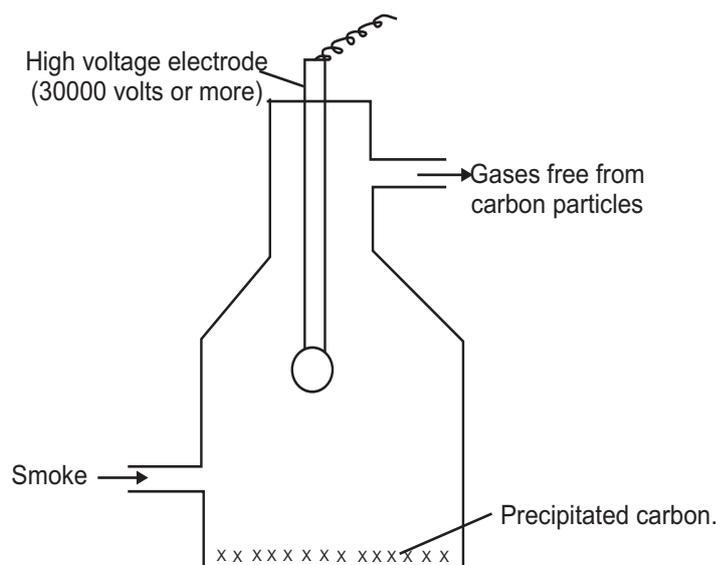


Fig.8.8 : Cottrell smoke precipitator

- (iii) **Smoke Precipitation :** Smoke particles are actually electrically charged colloidal particles of carbon in air. Precipitation of this carbon is done in a **Cottrell's Precipitator**. Smoke from chimneys is allowed to pass through a chamber having a number of metallic plates connected to a source of high potential as shown in Fig. 8.8. Charged particles of smoke get attracted to the oppositely charged electrode and get precipitated and hot purified air passes out.

Other applications in day to day life are :

- (i) **Photography :** A colloidal solution of silver bromide in gelatin is applied on glass plates or celluloid films to form photo-sensitive plates in photography.
- (ii) **Clotting of Blood :** Blood is a colloidal solution and is negatively charged. On applying a solution of $FeCl_3$ bleeding stops and clotting of the colloidal particles of blood takes place.
- (iii) **Rubber Plating :** Latex is a colloidal solution of negatively charged rubber particles. The object to be rubber plated is made the anode in the rubber plating bath. The negatively charged rubber particles move towards the anode and get deposited on it.

(iv) **Blue Colour of Sky** : Have you ever wondered why is the sky blue? It is because the colloidal dust particles floating about in the sky scatter blue light, that makes the sky appear blue. In the absence of these colloidal particles the sky would have appeared dark throughout.

8.8 EMULSION AND GEL

Emulsions are colloidal solutions in which both the dispersed phase and dispersion medium are liquids. However, the two liquids are immiscible, as miscible liquids will form true solution.

Emulsion are of two kinds :

- (a) **Oil-in-water emulsion** : Here the dispersed phase is oil while the dispersion medium is water. Milk is an example of this kind as in milk liquid fats are dispersed in water. Vanishing cream is another example.
- (b) **Water-in-oil emulsion** : Here dispersed phase is water and dispersion medium is oil. Butter, cod- liver oil, cold creams are examples of this type.

The liquids forming emulsion i.e. oil and water will separate out on keeping as they are immiscible. Therefore an emulsifying agent or emulsifier is added to stabilise the emulsion. Soap is a common **emulsifier**. The preparation of emulsion in the presence of an emulsifier is called emulsification.

How does an emulsifier work? It is believed that an emulsifier gets concentrated at the interface between oil and water i.e. the surface at which oil and water come in contact with each other. It acts as a binder between oil and water.

Applications of Emulsions - Emulsions play very important role in our daily life. Some of the common applications are given below :

1. The cleansing action of soap and synthetic detergents for washing clothes, bathing etc is based upon the formation of oil in water type emulsion.
2. Milk is an emulsion of fat in water. Milk cream and butter are also emulsions.
3. Various cold creams, vanishing creams, body lotions etc. are all emulsions.
4. Various oily drugs such as cod liver oil are administered in the form of emulsion for their better and faster absorption. Some ointments are also in the form of emulsions.
5. The digestion of fats in the intestine occurs by the process of emulsification.
6. Emulsions are used for concentrating the sulphide ores by froth flotation process. Finely powdered ore is treated with an oil emulsion and the mixture is vigorously agitated by compressed air when the ore particles are carried to the surface and removed.





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Gels - Gels are the type of colloids in which the dispersed phase is a liquid and the dispersion medium is a solid. Cheese, jelly, boot polish are common examples of gel. Most of the commonly used gels are hydrophilic colloidal solution in which a dilute solution, under suitable conditions set as elastic semi solid masses. For example 5% aqueous solution of gelatin in water on cooling forms the jelly block.

Gels may shrink on keeping by losing some of the liquid held by them. This is known as **syneresis** or resetting on standing.

Gels are divided in two categories elastic gels and non elastic gels. Elastic gels are reversible. When partly dehydrated on losing water, they change back into the original form on addition of water. The non elastic gels are not reversible.

Gels are useful in many ways. Silica, cheese, jelly, boot polish, curd are commonly used gels. Solidified alcohol fuel is a gel of alcohol in calcium acetate.

In recent past nano materials have attracted enormous interest because of their potential for wide ranging applications in number of fields like medicine, electronics and various industries. They can be metals, ceramics, polymeric materials or composite materials.

A material containing particles with dimension in the size range 1 nm – 100 nm in atleast one direction is termed as **nano material**. One nanometre is 10^{-9} m which is extremely small in size. It is about the size of three to five atoms lined up in a row.

Nano materials have been produced and in use for hundreds of years. The beautiful ruby red colour of some types of glass is due to the presence of nano particles of gold in it. The decorative lustre found on some articles of medieval pottery is due to nano particles of some metals in the glaze.

Nano materials fall in two categories (i)fullerenes and (ii) inorganic nano materials.

(i) Fullerenes

Fullerenes are allotropes of carbon which are hollow carbon spheres consisting of large number of carbon atoms bonded chemically like C_{60} .

(ii) Inorganic nano particles

Inorganic nano particles are made of metals, semiconductors or oxides with peculiar electrical, mechanical, optical or chemical properties.

Properties

Nanomaterials are available in great variety and the range of their properties and possible applications is enormous.

- (i) They are used for making miniature batteries, super absorbents, extremely tiny electronic devices, parts of automobiles and as packaging films.
- (ii) Nanocapsules and nanodevices present new possibilities for drug delivery, gene therapy, and medical diagnostics.
- (iii) Nanocomposites are obtained by mixing a small quantity of nano material to polymers. For example, adding such small amounts as 2% by volume of silicate nanoparticles to a polyimide resin increases the latter's strength by 100%. Addition of nanoparticles not only improves the mechanical properties, but has also been shown to improve thermal stability.
- (iv) Nano materials generally have high plasticity.
- (v) Due to their large surface, nanoparticles made of transition element oxides exhibit catalytic properties
- (vi) Magnetic nanoparticles show super paramagnetism and have lead to the discovery of a new class of permanent magnetic materials.

**WHAT YOU HAVE LEARNT**

- Size of the particles in the colloidal state is intermediate between that of suspension and true solution.
- There are eight different types of colloidal systems.
- Sols are classified on the basis of (a) interaction between dispersed phase and dispersion medium (b) molecular size of dispersed phase.
- Colloidal solutions are prepared by physical and chemical methods.
- The zig zag motion of colloidal particles is called Brownian motion.
- Colloidal size particles scatter light and so the path of light becomes visible in a semi darkened room due to dust particles.
- Colloidal particles may carry electric charge.
- A colloidal dispersion of a liquid in another liquid is called an emulsion.
- A colloidal solution of a liquid dispersed in a solid medium is called a gel.
- Colloids are extremely useful to mankind both in daily life and in industry.
- Nano materials contain particles with dimension of 1–100 nm in at least in one direction. They have special properties and find many applications.

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**TERMINAL EXERCISE**

- List three differences between a true solution and a colloidal solution.
- Describe one method of preparation of
 - a lyophilic colloid
 - a lyophobic colloid
- What are associated colloids?
- What is Brownian motion? How does it originate?
- Why bleeding from a fresh cut stops on applying alum?
- Two beakers A and B contain ferric hydroxide sol and NaCl solution respectively. When a beam of light is allowed to converge on them, (in a darkened room), beam of light is visible in beaker A but not in beaker B. Give the reason. What is this effect called?
- Define the following terms and give two examples of each
 - Gel
 - Sol
- Describe two important applications of colloidal solutions.
- Give two examples of emulsions used in daily life.
- Explain the role of emulsifier in an emulsion?
- What are nano materials? Give their three applications.

**ANSWERS TO THE INTEXT QUESTIONS****8.1**

- | | |
|---------------|--|
| Suspension | – Clay in water, Sand in water |
| Colloidal | – Milk, Blood, Boot polish, Face Cream, Jelly, Foam. |
| True Solution | – Sugar in water |
- | | |
|----------|-------------------|
| Sol | – Starch in water |
| Gel | – Silica gel |
| Aerosol | – Fog |
| Emulsion | – Milk |
- | | |
|----------|--|
| Alcosol | – When alcohol is the dispersion medium. |
| Hydrosol | – When water is the dispersion medium. |

- | | |
|---|-----------------------------------|
| 4. True solution | Colloidal solution |
| 1. Size of solute is less than 1 nm. | 1. Particle size (1–100) nm. |
| 2. Form transparent solution and allows light to pass through them. | 2. Path of light becomes visible. |

8.2

1. Gold sol, Platinum sol
2. As_2S_3 , $\text{Fe}(\text{OH})_3$ (Arsenious sulphide sol, ferric hydroxide sol)
3. (a) **Lyophilic sol** :
 1. easy to prepare
 2. affinity between dispersed phase and dispersion medium.
 3. Reversible

Lyophobic

1. special method used for preparation
 2. No affinity between the two phases.
 3. Not reversible
- (b) **Macromolecular** – The size of the colloidal particles large enough to fall in the colloidal dimensions.

Multimolecular – Individually the particles are not of colloidal dimensions but they aggregate to join together to form molecules of colloidal size.

4. Refer to section 8.3.2 (c)



MODULE - IV
CHEMICAL ENERGETICS

- 09. Chemical Thermodynamics
- 10. Spontaneity of Chemical Reactions

