7

THE COLLOIDAL SOLUTION

7.1 INTRODUCTION

You are familiar with solutions. They play an important role in our life. A large number of substances such as milk, butter, cheese, creams, coloured gems, boot polish, rubber, ink etc. also play an important role in our daily life. They are also solutions of some kind. They are colloidal solutions. 'Kolla' means glue and 'Oids' means like i.e. glue-like. The size of the particles in collodial solutions is bigger than the size of particles present in solutions of sugar in water or salt in water.

In this lesson, you will learn about the colloidal solutions, their types, classification, preparation and some important properties.

7.2 OBJECTIVES

After reading this lesson you will be able to :

- explain the difference between true solution, colloidal solution (colloids) and a suspension on the basis of practicle size.
- Explain types of colloidal solution.

- cite examples of colloids from daily life.
- classify colloids into lyophilic and lyophobic colloids.
- describe methods of preparation of colloids by
  a) physical method b) chemical method
- describe methods of purification of colloids like dialysis and electro-dialysis.
- recognise the importance of purification of colloids in daily life.
- explain the properties of colloids like heterogeneity, Brownian motion, Tyndall effect, electrical property due to the presence of charged particles.
- cite examples of the applications of colloidal solutions in daily life and industry.
- recognise the importance of emulsions and gels in daily life

7.3 DISTINCTION BETWEEN A TRUE SOLUTION, COLLOIDAL SOLUTION AND SUSPENSION.

The nature of all types of solutions depend upon the size of the solute particles. When the size of the solute particles lies between 1 to 100 nm, it behaves as a **colloid** or colloidal solution, if the size of the solute particles is greater than 100 nm, it exits as a *suspension* and if the size of the solute particle is less than 1nm it exits as a **true solution**. Therefore the colloidal solution is an intermediate state between a true solution and a suspension.
A comparison of the properties of these three types is given in table 7.1

TABLE 7.1 : Some important properties of true solutions, colloids and suspensions.

S.No.	Name of Property	True Solution	Colloidal Solution	Suspension
1.	Size	Size of particles is less than 1 nm	Size of particles is between 1nm and 100nm	Size of particles greater than 100 nm
2	Filtrability	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 standing	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 micro scope	Particles are invisible to the naked eye but their scattering effect can be viewed with the help of a microscope	Particles are visible to the naked eye
5	Separation	The solute particles and solvent cannot be separated by ordinary filteration or by ultra filteration.	The solute and solvent cannot be separated by ordinary filtera-tion but can be separated by ultra-filteration	The solute and solvent can be separated by ordi-nary filteration
6	Diffusion	Diffuse quickly	Diffuse slowly	Do not diffuse

7.4 PHASES OF COLLOIDAL SOLUTION

Colloidal solutions are heterogenous in nature and always consist of at least two phases ; the **disperse phase** and the **dispersion medium.**

- **Dispersed Phase :** It is the substance present in small proportion and consists of particles of colloidal size (1 to 100nm).
- **Dispersion Medium :** It is the medium in which the colloidal particles are dispersed. In a colloidal solution of sulphur in water, sulphur particles constitute the 'dispersed phase' and water is the 'dispersion medium'.

The two phases namely ; dispersed phase and dispersion medium can be solid, liquid or a 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 7.2. You should note that gases cannot form a colloidal solution between themselves, because of their property of diffusion to give homogenous mixtures

Table 7.2 Types of Colloidal Solutions

S. No.	Dispersed Phase	Dispersion Medium	Common Name	Examples
1.	Solid	Solid	Solid Sol	Coloured gemstones, coloured glasses
2.	Solid	Liquid	Sol	Paints, muddy water, gold sol, starch sol, arsenous sulphide sol
3.	Solid	Gas	Aerosol	Smoke, dust
4.	Liquid	Solid	Gel	Gellies, cheese
5.	Liquid	Liquid	Emulsion	Milk, cod liver oil
6.	Liquid	Gas	Liquid alcosol	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). Note that 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** and so on.

INTEXT QUESTIONS 7.1

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. Choose the correct word from those given within brackets to fill in the blanks .

(i) Milk is the example of _____ (a gel, an emulsion, a solution).

(ii) When alcohol is shaken with water, you get _____ (an emulsion, a solution, a suspension)

(iii) Cloud is formed when _____ (liquid disperses in liquid, liquid disperses in gas, gas disperses in liquid).

(iv) Whipped cream is _____ (an aerosol, gel, foam)

7.5 CLASSIFICATION OF COLLOIDS

Depending upon the interaction between the dispersed phase and the dispersion medium, colloidal solutions are classified into two types :

(a) Lyophilic Colloids

(b) Lyophobic Colloids

Let us learn about them in detail

(a) Lyophilic Colloids : The word lyophilic means **affinity** for solvent. Substances like gum, gelatine, starch etc. when mixed with a suitable solvent, directly pass into the colloidal state and a colloidal solution. The

sols thus obtained, are called lyophilic sols. An important characteristic of these sols is that if the dispersed phase is separated from the dispersion medium (say by evaporation) the sol can be made again by simply remixing with the medium. That is why, these sols are called 'reversible sols'. These sols are quite stable and do not need any other stabilizing agent. If water is the solvent, these are called **hydrophilic colloids.**

(b) **Lyophobic Colloids** : The word 'Lyophobic' means **less affinity** for solvent. Substances like metals, their hydroxides or sulphides etc. when simply mixed with the dispersion medium do not pass directly into a colloidal state. They have to be prepared by special methods (discussed later). These sols are readily precipitated and hence are not very stable. They require a stabilizing agent to remain in the colloidal form. They are ' irreversible sols ' because once precipitated, they do not give back the colloidal solution by mixing with solvent. If water is the solvent, these are called **hydrophobic Colloids .**

7.6 PREPARATION OF COLLOIDAL SOLUTIONS

As discussed earlier, the lyophilic sols can be prepared directly by mixing the substances 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 **colloidion.**

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

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

(i) **Physical method**
(ii) **Chemical method**

(i) **Physical method** : **Bredig's Arc Method**

This method is employed for obtaining colloidal solutions of metals like gold, silver, platinum etc. (fig 7.1)

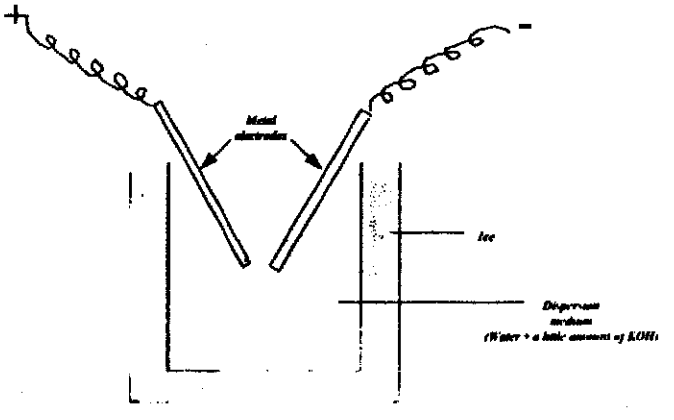

Fig. : Preparation of colloidal solution by Bredig's Arc Method.

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 gold sol.

ii) Chemical Method : 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 :

$$Br_2 + H_2S \longrightarrow S + 2\,HBr$$

$$HNO_3 + H_2S \longrightarrow H_2O + NO_2 + S$$

$Fe(OH)_3$ sol, $AS_2\,S_3$ sol can also be prepared by chemical methods.

7.7 PURIFICATION OF COLLOIDAL SOLUTIONS

When a colloidal solution is prepared, it often contains certain impurities of electrolytes which tend to destabilize it. The following methods are, therefore, used for purification of colloidal solutions.

i) **Dialysis**
ii) **Electrodialysis**

Dialysis : The process of separating the particles of colloids from those of crystalloids by diffusion of small particles through a parchment paper or animal memberane is called dialysis.
This separation is based on the principle that the particles of the crystalloids pass through the parchment paper whereas the particles of the colloids do not pass through. The apparatus is called a dialyser and is shown in figure 7.2.

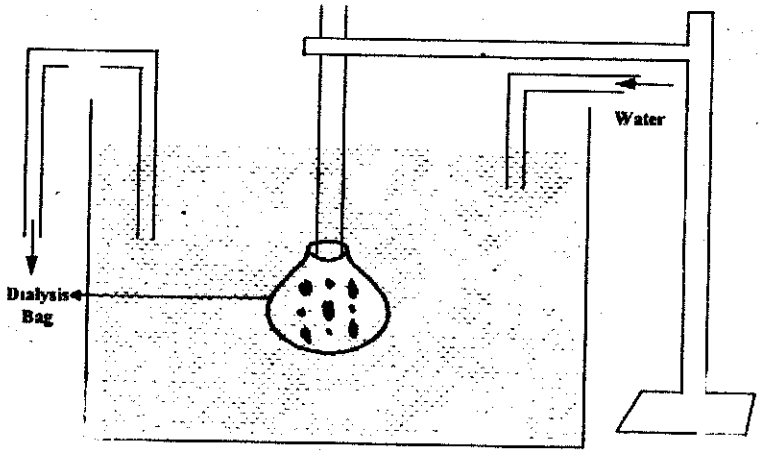

Fig 7.2 A dialyser

In the dialysis unit, the movement of ions across the membranes can be speeded up try applying an electric current through the electrodes introduced in the solution. This method is very fast and is known as **electrodialysis** (Fig 7.3)

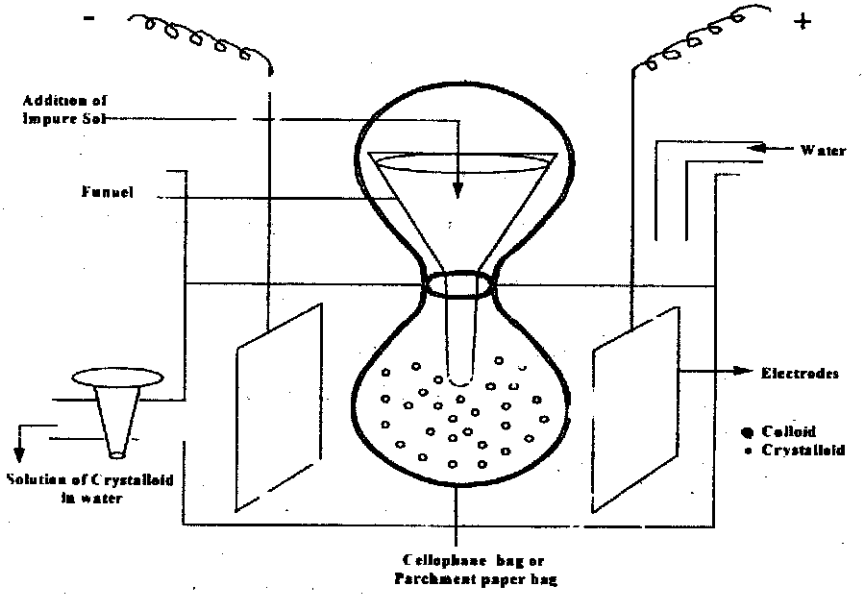

Fig 7.3 Electrodialysis

The most important use of dialysis is the purification of blood in the artificial kidney machines (fig 7.4) The dialysis membrane allows the small particles (ions etc.) to pass through but the colloidal size particles like haemoglobin do not pass through the membrane.

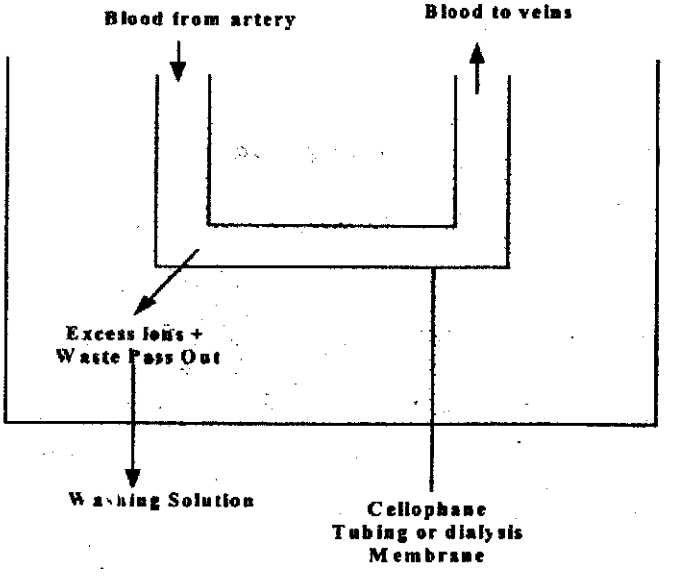

Fig. 7.4 Purification of Blood by Dialysis

INTEXT QUESTIONS 7.2

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. State True or False (T/F) against the following statements.

   i. Starch solution can be prepared by dissolving starch in warm

   ii. Lyophilic colloids have no affinity for solvent. water.

   iii. Colloidal particles pass through parchment paper memberane.

   iv. When hydrogen sulphide gas is passed through bromine water, it turns yellowish white.

4. **Fill in the blanks :**

   i. speeded up by _____

   ii. Sulphur sol can be prepared from dilute nitric acid by passing _____

   iii. The movement of ions across a membrane like parchment paper is Gelatin sol can be prepared by direct method as it is a _____ colloid.

   iv. Colloidion is a solution of cellulose nitrate in _____.

7.8 PROPERTIES OF COLLOIDS

The properties of colloids are discussed below :

a) Heterogencous character : Colloidal particles remain within their own boundary surfaces which separate 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.

b) Brownian Motion : Robert Brown, a botanist discovered in 1827 that 'pollen grains' placed in water do not remain at rest but move about continuously and randomly Later on this phenomenon was also observed in colloidal solutions. When the particles of a colloidal solution were viewed under an Ultra microscope, the particles were seen to be in constant motion in zig - zag path in all possible directions.

Brownian Motion is the zig-zag movement of colloidal particles continuously and randomly (Fig 7.5) Brownian motion arises because of the impact of the molecules of the solvent on the colloidal particles. The forces are unequal from different directions. Hence it causes the particles to move in a zig zag way.

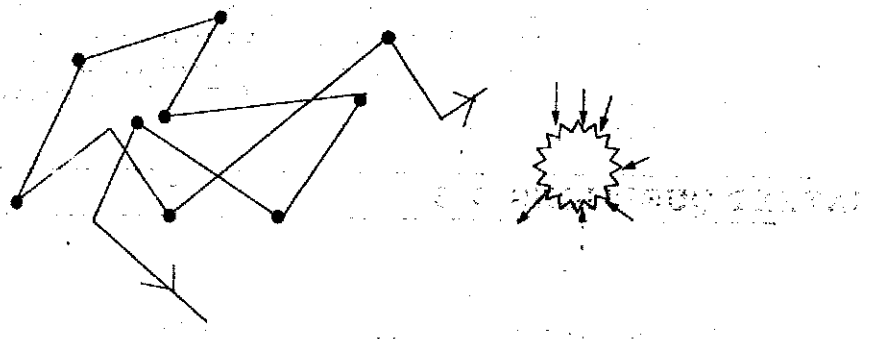

Fig 7.5 Brownian Movement

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 7 6). The same effect is noticed when a beam of sunlight enters a dark room through a slit when the beam of light becomes visible through the room. This happens due to the scattering of light by particles of dust in the air.

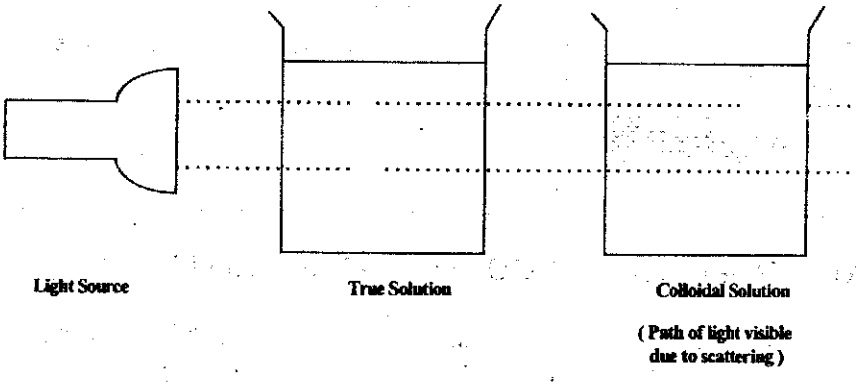

Fig 7.6 The Tyndall Effect

d) **Electrical Properties** : The particles of a colloidal solution 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. The charge on the colloidal particles arises because of many reasons. One of them is 'dissociation of the molecular electrolyte on the surface. For example when H_2S molecules get absorbed on the surface of colloidal particles of As_2S_3 (while preparation of As_2S_3) the H_2S molecules dissociate to H^+ and S^{2-} ions. H^+ ions are lost to the medium but S^{2-} remain on the surface of the colloid as $(Ag_2S_3)S^{2-}$. Hence arsenous sulphide is a negatively charged colloid, whereas $Fe(OH)_3$ sol are positively charged due to self dissociation and loss of OH^- to the medium. So they become [$Fe(OH)_3$] Fe^{3+} . The existence of charge on a colloidal particle is shown by a process called electrophoresis'.

INTEXT QUESTIONS 7.3

1. Fill in the blanks

i. Colloidal solutions are _____ in nature.

ii. Scattering of light by particles of colloidal size is called _____ effect.

iii. Ferric hydroxide sol is positively charged due to adsorption of _____ ions.

iv. Charge on the colloid is indicated by _____.

2. **Give one example of each of the following :**

i. Positi ely charged colloid

.....

ii. Negatively charged colloid

.....

3. Put a tick (✓) mark against the correct statement and a cross (×) mark against the wrong statement in the following

i. Starch is a Lyophilic colloid

ii. Brownian motion is seen in all solutions.

7.9 APPLICATIONS OF COLLOIDAL SOLUTION

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

i) **Sewage disposal :** Colloidal particles of dirt, wind etc. carry electric charge. When sewage is allowed to pass through metal plates kept at a high potential, 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 from alum. Hence the mud particles settle down and the water can be filtered and used.

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 Precipitation.** Smoke from chimneys is allowed to pass through a chamber having a number of metal plates attached to a metal wire connected to a source of high potential as shown in figure 7.7. Charged particles of smoke get attracted to the oppositively charged electrode and get precipitated and, hot purified air passes out.

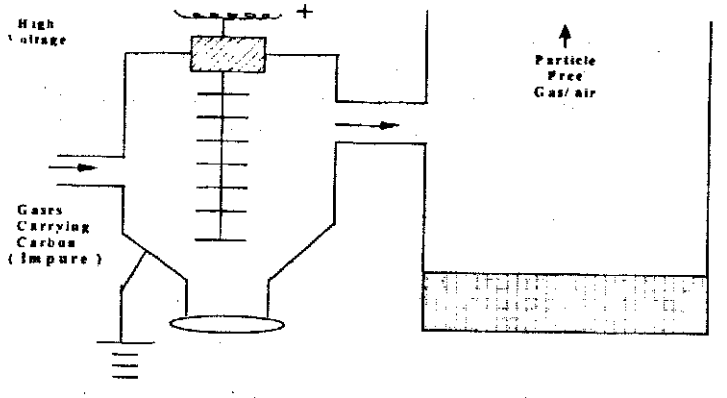

Fig 7.7 A Precipitator

Other applications in day to day life are :

i) **Photography :** A colloidal solution of silver bromide in gelatine is applied on glass plates or celluloid films to form 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 blood occurs. This happens because Fe^{3+} ions neutralize the ion charges on the colloidal particles of blood and clottingof 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. this makes the sky appear blue. In the absence of these colloidal particles the sky would have appeared dark throughout.

v) **Tail of Comet :** You must have watched a comet across the sky. Did you notice that comet leaves a tail behind? As the comet flies with tremendous velocity, it leaves tiny solid particles, suspended in the air. These particles scatter light (Tyndall effect) and so you see a luminous tail of the comet.

7.10 IMPORTANCE OF EMULSIONS AND GELS

> Emulsions are colloidal solutions in which the dispersed phase and the dispersion medium, both are liquids

Milk is an example of emulsion in which particles of liquid fat are dispersed in water. Cod liver oil is another example of emulsion in which water is dispersed in the oil.

To get a stable emulsion, small quantities of certain substances are added to it. These are called "Emulsifying Agents" or emulsifiers. The role of an emulsifier can be explained taking the example of soap as an emulsifier. A molecule of soap consist of two parts. The hydro carbon part which is soluble in oil and polar part which is soluble in water.

For example R – COO⁻ Na⁺

R → Hydrocarbon → Soluble in Oil

COO⁻ Na⁺ → Polar → Soluble in water

Thus, if a drop of oil is surrounded by soap solution, the R - part of soap remains in oil and $COO^- Na^+$ part remains in water. As a result the interfaced tension between oil and water decreases and it forms an emulsion. This principle backs in understanding the process of washing dirt from clothes with soap.

Jellies, cheese, butter etc. are example of gels in daily life. Emulsions are also very useful in daily life. Cosmetics, drugs, various lotions, face creams, shaving creams, ointments etc. are also emulsions in either oil or in water. Even dettol and Lyzol which are commonly used disinfectants are emulsions. Emulsions also find various applications in industries. For e.g. in the "Froth Flotation Process" for purifying sulphide ore, the ore is treated in an oil emulsion. Fats are digested in the intestines in our body due to formation of emulsions. It is easy for digestive enzymes to work on emulsified fat.

> **Gels are those colloidal solutions where a liquid is dispersed in a solid as the dispersion medium.**

You must have seen a small cloth bag in a medicine box, containing tablets. That is "silica gel". It is used for absorbing moisture from air and keeping the tablets dry.

7.11 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 nature of dispersion medium.
- Colloidal solutions are prepared by physical method and chemical methods.
- Soluble impurities in colloids can be removed by dialysis.
- 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.

7.12 TERMINAL EXERCISE

1. Choose the correct alternative :

(a) The size of the colloidal particles is of the order

i.) 1×10^{-10} cm to 1×10^{-8} cm

ii.) 1×10^{-7} cm to 1×10^{-5} cm

iii.) 2×10^{-3} cm to 2×10^{-2} cm

iv.) 2×10^{-2} cm to 1×10^{-1} cm

(b) Colloidal particles can be seen by

i.) the naked eye

ii.) an ultramicroscopic

iii.) an ordinary microscope

iv.) a telescope

(c) Gem stones are colloidal solutions of

i.) solid in solid type

ii.) gas in solid type

iii.) liquid in solid type

iv.) solid in liquid type

2. List three differences between true solution and a colloidal solution.

.....

3. Describe one method of preparation of

a) a lyophilic colloid

b) a lyophobic colloid

.....

4. What is Brownian motion ? How does it originate ?

.....

5. Describe the method used to purify starch sol from soluble salt impurity.

.....

6. Two beakers A and B contain Ferric hyodroxide 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 breaker B. Give the reason. What is this effect called ?

.....

7. Define the following terms and give two examples of each

i) Gel

ii) Sol

.....

8. Describe two important applications of colloidal solutions.

.....

9. Give two examples of emulsions used in daily life.

.....

CHECK YOUR ANSWERS

INTEXT QUESTIONS 7.1

Suspension - Clay in water, Sand in Water

Colloidal Solution - Milk, Blood, Boot polish , Face Cream Jelly, Foam.

True Solution - Sugar in water

2) Sol - Starch in water

Gel - Silica gel

Aerosol- Fog

Emulsion - Milk

3) Alcosol - When alcohol is the dispersion medium.

Hydrosol - When water is the dispersion medium.

4. i) Emulsion ii) A solution iii) Liquid disperses in a gas iv) Foam

INTEXT QUESTIONS 7.2

1) Gold, Platinum

2) As_2S_3, $Fe(OH)_3$ (Arsenous salphide sol, ferric hydroxide sol)

3) (i) False (iii) False (ii) True (iv) True

4) (i) Electro dialysis

(ii) H_2S

(iii) Lyophilic

(iv) Alcohol

INTEXT QUESTIONS 7.3

1. (i) Heterogeneous (ii) Tyndall effect (iii) Ferric (Fe^{3+}) ions (iv) Electrophoresis

2. (i) Ferric hydroxide sol (ii) Arsenous sulphide sol

3. (i) ✓ (ii) ×

TERMINAL EXERCISE

1. (a) ii (b) ii (c) i
2. See table 7.1
3. See Section 7.6
4. See Section 7.8
5. Dialysis for description see section 7.7
6. Due to tyndal effect shown by Ferric hydroxide sol as it is in colloidal state.
7. Gel is formed when a liquid is dispersed in a solid. It has a jelly like appearance. Sol is formed when a solid is dispersed in a liquid to form a colloidal solution. It has a liquid like appeãrance.

   Examples of gel - Jelly, silica jel

   Examples of sols - Starch sol, gum
8. See section 7.9
9. Emulsions in daily life - dettol, milk