



SOLUTION AND COLLOIDS

Chapter 10

Teaching Periods

8

Assessment

1

Weightage

10



Students will be able to:

- **List** the characteristics of colloids and suspension that distinguish them from solutions.
- **Define** hydrophilic and hydrophobic molecules.
- **Explain** the nature of solutions in liquid phase giving examples of completely miscible, partially miscible and immiscible liquid-liquid solutions.
- **Explain** the effect of temperature on solubility.
- **Express** solution concentration in terms of mass percent, molality, molarity, parts per million, billion and trillion and mole fraction.
- **Define** Raoult's law with suitable examples.
- **Define** the term colligative property.
- **List** some colligative properties of liquids.
- **Describe** on a particle basis why a solution has a lower vapor pressure than the pure solvent.
- **Explain** on a particle basis how the addition of a solute to a pure solvent causes an elevation of the boiling point and depression of the freezing point of the resultant solution.
- **Explain** osmotic pressure, reverse osmosis and give their daily life applications.
- **Describe** types of colloids and their properties.

are physically mixed but no chemical change occurs during their mixing. Particles of solute and solvent in a solution (atoms, ions or molecules) are extremely small having a diameter of approximately less than 1 nm, this indicates that.

- Solution is a transparent mixture of its components.
- Component of solution cannot be separated by filtration.
- Light cannot be scattered though the solutions (Tyndall effect).

INTRODUCTION

Let's consider a spoonful sugar is put into water, it dispersed uniformly so that we cannot see the particles of sugar. In chemistry "**Solution is a type of homogenous mixture in which individual components cannot be distinguished**". The term solution is not restricted to the mixture of solid into liquid but broadly cover up the uniform mixing of solids liquids and gases. A solution consists of a solvent along with one or more solutes. Solvent is the medium in which solute is dissolved. Generally, the component present in larger amount is called solvent and the other which is in smaller amount is called solute. The components of solution may be more than two. For example sea water is solution of many components such as NaCl, CaCl₂, MgCl₂, etc. A solution which consists of only two components is known as binary solution. There are various reasons of preparing solution, some time we prepare them for specific reaction and some time for particular analytical or domestic purpose.

10.1 GENERAL PROPERTIES OF SOLUTION

Solution is a single phase mixture with no boundaries separating its components. Substances in a solution



Whenever a solute dissolves in a solvent, there should be three types of intermolecular attractions involved, the solute-solute, solvent-solvent and solute-solvent. The basic rule in the formation of a solution is that the attraction between solute-solvent molecules becomes equal or greater than solute-solute and solvent-solvent molecules. The process of solution preparation is known as dissolution during which solute-solute interactions is broken down and solvent particles surrounds them from all sides to establish new stronger solute-solvent associations.

Generally, dissolution process is either endothermic or exothermic. This can be realized by studying two energies involve in the process. Lattice energy is the energy required to separate solute particles from solid crystal into solution and the solvation energy which released when interaction of solute and solvent particles takes place. Ions with greater charge and smaller size have high solvation energy hence their dissolution in exothermic. On the other hand many solid substances have strong particle binding in their crystal lattice. They must absorb energy from the solution and make the process endothermic. The energy difference of the above two processes is recognized as heat of solution. It is the change in enthalpy when a substance dissolves in solvent to make a solution at constant pressure.

10.1.1 Solution, Suspension and Colloids

Have you ever seen muddy water in a pond or even in your domestic water connection? This is a heterogeneous mixture of mud in water. If you fill a glass with muddy water you will observed that mud will be settled down after few minutes. Why this happens? This is due to the large size of solute particles, usually more than 1000nm. This muddy water is not a solution but we use another term suspension.

“Suspension is a cloudy, heterogeneous mixture whose dispersed particles are settled down eventually”. The components of suspension may be identified as dispersed phase and dispersion medium. Another terminology use in this connection is colloid which can be placed in between solution and suspension. The particle size of colloids is neither too much large nor so small. It is in the range of 1 nm to 1000 nm. Colloids refer as the translucent heterogeneous mixture of microscopically dispersed particles into a dispersion medium which cannot be settled out.

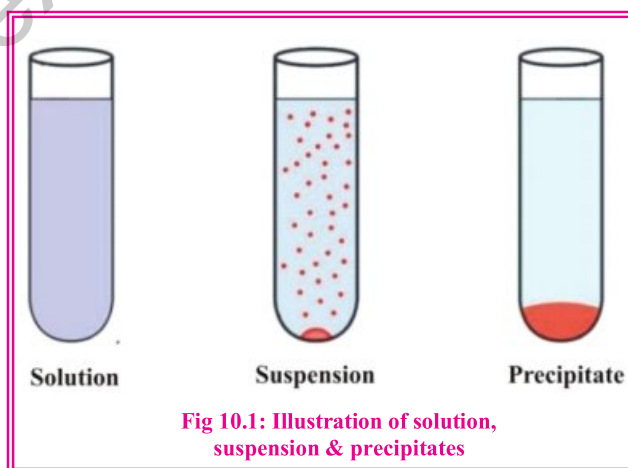


Fig 10.1: Illustration of solution, suspension & precipitates



Types	Physical Appearance	Particle Size	Visibility	Settling	Example
True Solution	Transparent	Less than 1 nm	Invisible to naked eye	Particles do not settle down	Glucose Solution
Colloidal Solution	Translucent	Between 1 nm to 1000nm	Visible under powerful microscope	Particles do not settle down to their own but can be made by coagulation	Milk
Suspension	Opaque	Above 1000nm	Easily visible	Particles settle down to their own	Mud in water

10.1.2 Hydrophilic and Hydrophobic Molecules

Many solutions in daily life are water based that means water is used as solvent. Did you work on acid and base solution in your chemistry laboratory? Have you ever think about the composition of salt solution, glucose solution, rain water, cola bottle etc, these all are aqueous solutions. It is a well known fact that water is a polar molecule therefore when an ionic or polar covalent substance is mixed into water; an interaction of positive and negative terminal of water molecules with the particles of dissolving substance (ions or molecules) develops which makes the molecules evenly distributed throughout the water in a homogenous pattern. Thus **“solute substances whose particles (ions or molecules) strongly associated with water are categorized into hydrophilic molecules”**. The term hydrophilic is derived from hydro mean water and phillic means to attract. Ethanol, acetic acid, amino acid, acetone etc are polar covalent molecules. They on dissolving in water form hydrogen bonding and thus form a solution.

On the other hand there are some substance which do not mix into water consist of hydrophobic molecules. These molecules are structurally non polar in nature therefore they do not have ability to attract water molecules (hydro; water and phobic; to dislike). Many organic molecules are structurally non polar when mix into water they do not attract with solvent molecules and show their hydrophobic behavior thus do not form a solution and said to be hydrophobic. For example Petrol, Benzene, Toluene etc.

10.1.3 The nature of Solution in Liquid Phase

On the basis of solids, liquids or gaseous state, there are nine types of solution. Whenever a solution of two liquids is needed to be prepared, we should have some know how about their chemical nature. Miscibility refers to the ability of two liquids to mix into each other in all proportion. Depending upon relative miscibility of two liquids we can develop three possibilities.



(i) Completely miscible liquids:

When two liquids are mixed into each other in all proportion to form a homogenous mixture, they are said to be completely miscible.

While studying on molecular level, the intermolecular attractions of the two completely miscible liquids found to be of similar order. For example methanol and water both are polar molecules and on mixing they completely soluble into each other. The reason is that both water and methanol molecules possess same extent of hydrogen bonding in their pure liquid states as well as in mixture form.

Benzene and toluene both are non polar liquids. Referring the rule of thumb “likes dissolves likes they are categorized into completely miscible liquid pair. Again switch your mind towards their molecular attraction; the molecules of benzene and toluene in their pure liquid states as well as in mixture form interact through London dispersion forces.

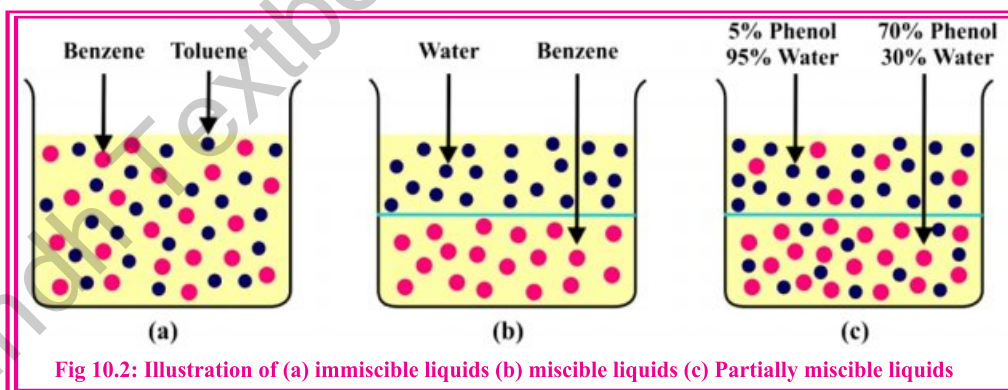
(ii) Partially Miscible Liquids

Some liquids dissolve into each other to a limited extent up to a certain concentration. When such liquids mix into each other, they form two separate phases. Each phase is the saturated solution of the two liquids in-which one serves as solute and other is solvent.

For example when phenol is mixed into water at 25°C, a two phase solution is formed in which upper layer represents 5% phenol in 95% water while lower layer consists of 70% phenol in 30% water.

(iii) Completely Immiscible Liquids

When two liquids do not mix into each other and do not form solution are called immiscible liquids. For example water is polar liquid and benzene is non polar. These two liquid are totally immiscible in all proportion and form two separate layers on mixing.



Self Assessment

If you have water in one container and petrol in another container, which solvent is suitable for dissolving (i) grease (ii) common salt? Explain why?



10.1.4 Effect of Temperature and Pressure on solubility of solution

Saturated solution is generally prepared by mixing maximum amount of solute that should be dissolved in fixed amount of solvent. **“Solubility is the amount of solute (in grams) that can be dissolved in a fixed quantity (volume) of a particular solvent to prepare a saturated solution at a specific temperature”**. Solubility of a substance is fundamentally depends on chemical nature of solute and solvent particles. However, it notably changes with temperature and pressure.

Effect of Temperature:

Solubility of many solids in liquid increases with the rise of temperature. This is attributed with the fact that rise of temperature increases the kinetic energy and randomness of particles and create more spaces among solvent molecules in which solid solute particles accommodate. However, some solids show a decrease trend in solubility with the rise of temperature. This dual behavior in the solubility of solids with the temperature can be predicted by whether heat absorb or evolve in the formation of solution. Many solids dissolve into solvent with the absorption of heat, solubility of these substances increases with the rise in temperature.

The dissolution of some solids (AlCl_3 , Na_2SO_4 etc) and many liquids as well as gases in liquid solvent is carried out by exothermic process. Solubility of these substances decreases with the rise of temperature.

Effect of Pressure:

Solubility of solids and liquids in a liquid solvent is not appreciably change by altering the pressure. However the solubility of gases into liquid is significantly affected by pressure. In theoretical aspect the dissolution of gases into liquid is an equilibrium process. This means that a simultaneous entrance and exist of gas molecules from solution occur. Thus an increases in pressure increases the number of gas molecule so the rate of entrance of gas molecules into solution becomes higher than its exit. Conclusively solubility of gas into liquid increases with the rise of pressure.



Do You Know?

Carbonated water is a solution of CO_2 in water under high pressure. When cork of the bottle is opened, pressure reduces to atmospheric pressure due to which solubility of CO_2 in water decreases which can be observed in the form of bubbles on the surface.

10.2 CONCENTRATION UNITS

The term concentration expresses the amount of solute dissolved in fixed amount of solvent or solution. While performing chemistry practical, it is usually necessary to know what amount of solute is present in the given solution. There are several ways to express the concentration of solution each has its own significance for particular work.

10.2.1 Percentage Composition

This unit is frequently used in chemistry. It may be studied in term of w/w, w/v, v/w and v/v. The mass percent (w/w %) may be define as the mass of solute in gram per 100 gram of solution mathematically it may written as



$$\text{Mass percent} = \left(\frac{\text{mass of solute}}{\text{mass of solution}} \right) \times 100$$

For example a 12% (w/w) aqueous sugar solution means 12g of sugar dissolves in 100g solution or 88g of water.

10.2.2 Molarity (M)

It is the number of moles of solute dissolved per dm^3 of solution.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in dm}^3}$$

For example the molarity of 20g NaOH in 1dm^3 aqueous solution is 0.5M.

Molarity is temperature dependent because the volume of solution decreases or increase with temperature.

10.2.3 Molality (m)

It is the number of moles of solute per kilogram of solvent.

$$\text{Molality} = \frac{\text{moles of solute}}{\text{kilogram of solvent}}$$

For example the molality of 18g glucose in 1kg water is 0.1 mol/kg.

Molality does not change with temperature because masses remain unchanged by heating or cooling.

10.2.4 Mole Fraction (X)

This unit is used when two or more components are present in the solution. It is the ratio of number of moles of one component to that of all components of solution.

$$X_A = \frac{\text{moles of substance A}}{\text{total moles of solution}} \quad X_B = \frac{\text{moles of substance B}}{\text{total moles of solution}}$$

The sum of mole fractions of all the components of a solution is always a unity

$$X_A + X_B = 1$$

For example if a solution is made up of 1 mole methanol in 4 moles water, the mole fraction of methanol will be 0.2 and water will be 0.8. Now if we add the mole fraction of both methanol and water we get unity.

$$X_{\text{methanol}} + X_{\text{water}} = 0.2 + 0.8 = 1$$

10.2.5 Parts Per million, Billion and Trillion

These units are used in analytical or biochemical research works when solute is present in very small quantity.

(i) **Parts per million (ppm)** is the number of parts or amount (mass or volume) of solute per million parts (10^6) of the amount (mass or volume) of solution.

$$\text{ppm} = \frac{\text{Amount of solute (mass or volume)}}{\text{Amount of solution (mass or volume)}} \times 10^6$$

For example when 1 mg of a solid present in 1dm^3 of solution the concentration is said to be 1 parts per million (ppm).



(ii) Parts per billion (ppb) is the number of parts or amount (mass or volume) of solute per billion parts (10^9) of the amount (mass or volume) of solution.

$$\text{ppb} = \frac{\text{Amount of solute (mass or volume)}}{\text{Amount of solution (mass or volume)}} \times 10^9$$

For example if 1 milligram of a substance present in 1000 dm^3 of solution, its concentration is marked as 1 ppb.

(iii) Parts per trillion (ppt) is the number of parts or amount (mass or volume) of solute per trillion parts (10^{12}) of the amount (mass or volume) of solution.

$$\text{ppt} = \frac{\text{Amount of solute (mass or volume)}}{\text{Amount of solution (mass or volume)}} \times 10^{12}$$

For example if 1 microgram of a substance present in 1000 dm^3 of solution.

Example 10.1

6.24g caustic soda (NaOH) is dissolved in water and the solution is made to 100cm^3 in a volumetric flask. Determine the concentration of this solution in term of molarity.

Solution:

$$\text{Molarity of Solution} = \frac{\text{Moles of NaOH}}{\text{Volume of Solution (dm}^3\text{)}}$$

$$\text{Molarity of Solution} = \frac{6.24 / 40}{100 / 1000}$$

$$\text{Molarity of Solution} = 1.56 \text{ mol/dm}^3$$

Example 10.2

An aqueous solution of 1.2 molality is prepared by dissolving some amount of oxalic acid into 475g water. Determine the mass of oxalic acid in the solution. (molecular mass of oxalic acid is 126 g/mol)

Solution:

$$\text{Molality} = \frac{\text{moles of solute (oxalic acid)}}{\text{mass of solvent in kg (water)}}$$

$$1.2 = \frac{\text{mass of oxalic acid}}{126 \times 0.475}$$

$$\text{mass of oxalic acid} = 1.2 \times 126 \times 0.475 = 71.82\text{g}$$



Example 10.3

45g glucose dissolves in 72g water to make a solution. Calculate the mole fraction of glucose and water in the solution.

Solution:

First we determine the number of moles of glucose and water from their given masses

$$\text{Moles of glucose} = \frac{45}{180} = 0.25$$

$$\text{Moles of water} = \frac{72}{18} = 4$$

Now

$$\text{Mole fraction of glucose} = X_2 = \frac{n_2}{n_1 + n_2} = \frac{0.25}{4 + 0.25} = 0.0588$$

$$\text{Mole fraction of water} = X_1 = \frac{n_1}{n_1 + n_2} = \frac{4}{4 + 0.25} = 0.941$$

Example 10.4

Calculate the molality of a 12% urea solution (molar mass of urea is 60g/mol)

Solution:

(i) 12% urea solution represents 12g urea in 100g solution thus the mass of water is calculated as

$$\text{Mass of water in gram} = 100 - 12 = 88\text{g}$$

$$\text{Mass of water in kg} = \frac{88}{1000} = 0.088\text{kg}$$

$$\text{(ii) No. of moles of urea} = \frac{\text{mass of urea}}{\text{molar mass of urea}}$$

$$\text{No. of moles of urea} = \frac{12}{60} = 0.2 \text{ moles}$$

$$\text{(iii) Molality of urea} = \frac{\text{moles of urea}}{\text{mass of water (kg)}}$$

$$\text{Molality of urea} = \frac{0.2}{0.088} = 2.27 \text{ mol/kg}$$



Example 10.5

In the analysis of water sample, it was reported that 1g of water contains 6.34×10^{-3} mg magnesium ions. Calculate the concentration of magnesium ions in ppm.

Solution:

We know that

$$\text{ppm} = \frac{\text{amount of solute}}{\text{amount of solvent}} \times 10^6$$

$$\text{ppm} = \frac{6.34 \times 10^{-3} \text{ mg}}{1 \text{ g}} \times 10^6$$

$$\text{ppm} = \frac{6.34 \times 10^{-3} \text{ mg}}{10^3 \text{ mg}} \times 10^6 = 6.34$$

Thus concentration of magnesium ions in water = 6.34ppm

10.3 RAOULT'S LAW

It has been learnt in chapter-5 that when a liquid is put in a close vessel it maintains equilibrium with its vapours and the pressure of vapours above the surface of a liquid at equilibrium is known as vapours pressure. If now we prepare a solution of volatile solvent with non volatile solute and correlate the vapour pressure of pure solvent with that of solution we find that the vapours pressure of solution is lowered than that of pure solvent. Indeed the escaping of pure volatile solvent is much faster since all surface molecules belongs to solvent molecules but in a solution a part of surface is also occupied by non volatile solute particles. This decreases the number of solvent molecules on the surface and reduces the escaping tendency of the solvent molecules which results in lowering of vapours pressure of solution as compared to pure solvent.

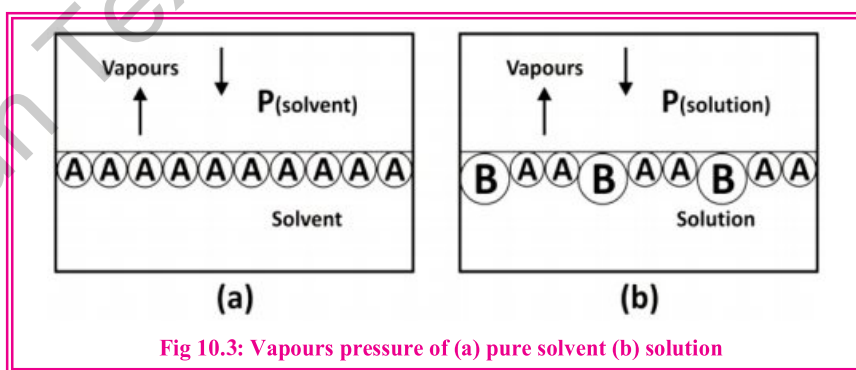


Fig 10.3: Vapours pressure of (a) pure solvent (b) solution

A French chemist F.M. Raoult studied these phenomena of lowering of vapours pressure by the effect of solute particles in a solution and formulated a law (1887) known as



Raoult law. For a non volatile solute system it states as **“the vapours pressure of a solution which is a made up of non volatile solute with volatile solvent is directly proportion to the mole fraction of solvent”**.

$$P \propto X_1$$
$$P = P^\circ X_1 \text{----- (i)}$$

Here **P** specifies the vapours pressure of solution, **P[°]** represents vapours pressure of solvent and **X₁** is the mole fraction of solvent.

Since in a binary solution $X_1 + X_2 = 1$, hence $X_1 = 1 - X_2$

Putting the value of X_1 in eq. (i) we get

$$P = P^\circ (1 - X_2)$$
$$P = P^\circ - P^\circ X_2$$
$$P^\circ - P = P^\circ X_2$$
$$\Delta P = P^\circ X_2 \text{----- (ii)}$$

Equation (ii) represents the second form of Raoult's law which states as the lowering of vapour pressure is directly proportional to the mole fraction of solute.

$$\frac{\Delta P}{P^\circ} = X_2 \text{----- (iii)}$$

Here $\frac{\Delta P}{P^\circ}$ is referred as relative lowering in vapours pressure.

Eq. (iii) represents third form of Raoult law which states as the relative lowering of vapours pressure is equal to the mole fraction of solute.

Raoult's law is also applicable on a binary solution made up of two miscible volatile liquids having similar order of polarity and molecular size. The partial pressure of each liquid in the mixture is equal to the vapours pressure of pure component multiplied by its mole fraction and may be written as

$$P_A = P^\circ_A X_A \quad \text{and} \quad P_B = P^\circ_B X_B$$

Thus the total pressure of solution is equal to the sum of partial pressure of both liquid in the mixture.

$$P_t = P^\circ_A X_A + P^\circ_B X_B \text{----- (iv)}$$



Self Assessment

- (i) Why is the vapours pressure of an aqueous solution is lowered than pure water?
- (ii) Under what conditions does Raoult law is applicable?



Example 10.6

Glucose is a non volatile solute in water. A glucose solution contains 0.15 moles glucose and 5.8 moles water at 20°C. Determine the lowering in the vapour pressure if the vapour pressure of pure water at 20°C is 17.5 torr. (Assume solution is an ideal)

Solution:

First we determine the mole fraction of glucose.

$$X_2 = \frac{n_2}{n_1 + n_2}$$
$$X_2 = \frac{0.15}{5.8 + 0.15} = 0.0252$$

Now applying second form of Raoult law

$$\Delta P = P^\circ X_2$$

$$\Delta P = 17.5 \times 0.0252$$

$$\Delta P = 0.441 \text{ torr}$$

Example 10.7

The vapour pressure of a pure liquid A is 37mm Hg at 27°C. It is mixed into another liquid B to make a solution. The vapour pressure of A in the solution is found to be 33mm Hg. Calculate the mole fraction of A (Assume it obeys Raoult's law)

Solution:

$$P_A^\circ = 37 \text{ mm Hg}$$

$$P_A = 33 \text{ mm Hg}$$

$$X_A = ?$$

Applying the relationship of Raoult law

$$P_A = P_A^\circ X_A$$

$$X_A = \frac{P_A}{P_A^\circ} = \frac{33}{37} = 0.89$$

Ideal and Non Ideal Solution

Binary solutions of two miscible liquids are categorized into ideal and non ideal solutions. The solution which perfectly obey the Raoult's law or obey the relationship mentioned in equation (iv) are referred as ideal solutions, however many solutions do not satisfy Raoult law due to the difference in the attractive forces and molecular size of solute and solvent particles. These solutions are formed by the change in volume and enthalpy and known as non ideal solution.



There are four distinct characteristics of an ideal solution.

- (i) It obeys Raoult's law at all temperatures and concentrations.
- (ii) The molecular interaction of liquid A-A, B-B and A-B remains almost the same.
- (iii) No heat is absorbed or evolved in the formation of an ideal solution ($\Delta H = 0$).
- (iv) No change in volume takes place in the formation of an ideal solution ($\Delta V = 0$).

Examples of liquid pairs which form ideal solutions on mixing are methanol-ethanol, benzene-toluene etc.



Self Assessment

- (i) What does an ideal solution mean?
- (ii) Which of the mixtures containing the following pairs obey Raoult's law?
 - Methanol and Ethanol
 - Toluene and xylene
 - Methanol and water

10.4 COLLIGATIVE PROPERTIES OF SOLUTION

Certain physical properties of solutions depend upon the number of solute particles rather than their chemical nature; these are referred to as colligative properties. (Colligative means collective). Examples are lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure. We specifically focus on the colligative properties of solutions of non-volatile and non-electrolyte solutes.

10.4.1 Lowering of Vapour Pressure

In the previous section, we have studied about how the vapour pressure of a solution containing a non-volatile and non-electrolyte solute is lowered as compared to its pure solvent. Recall the second statement of Raoult's law which tells that the lowering in vapour pressure of a solution is directly proportional to the mole fraction of solute.

$$\Delta P = P^\circ X_2$$

Thus the greater the number of non-volatile solute particles, the more the lowering in vapour pressure (ΔP) of the solution.

10.4.2 Elevation of Boiling Point and Depression of Freezing Point

The temperature at which the vapour pressure of a liquid becomes equal to atmospheric pressure (1 atm) is known as the normal boiling point. If a non-volatile and non-electrolyte solute (solid) is dissolved into a volatile solvent, its vapour pressure is found to be lower than 1 atmosphere. Since a liquid boils only when its vapour pressure becomes equal to atmospheric pressure, some more heat is needed for the solution to reach its vapour pressure of 1 atmosphere. This concludes that the boiling point of a solution is greater than the boiling point of the pure solvent. **“Boiling point of a solution of non-volatile solute is higher than pure solvent, this is a colligative property and known as elevation of boiling point (ΔT_b)”.**



To understand how is the elevation in boiling point of solution occur by adding non volatile solute let us consider graph of vapours pressure v/s temperature of pure solvent (curve AB) and solution (curve CD) in fig 10.5. Both curves meet the line of atmospheric pressure at point A and C respectively. It is specified from the graph that the boiling point of solution (T_b) is higher than pure solvent (T_b°) for equalization of vapours pressure to the atmospheric level.

Depression of freezing point

We know that kinetic energy of liquid molecules decreases on cooling and molecules approaches one another more closely and liquid finally turns into solid. “Freezing point of a liquid is the temperature at which liquid and solid phases co exists in equilibrium with the same vapours pressure”.

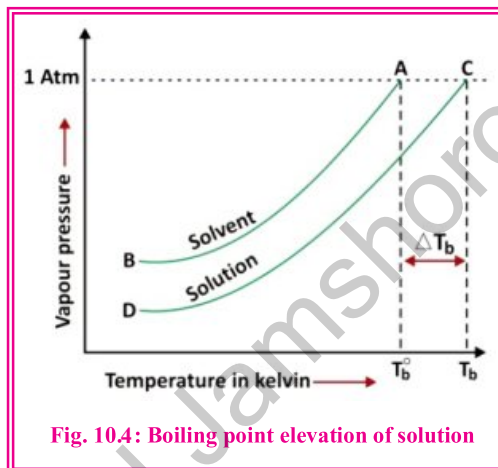


Fig. 10.4: Boiling point elevation of solution

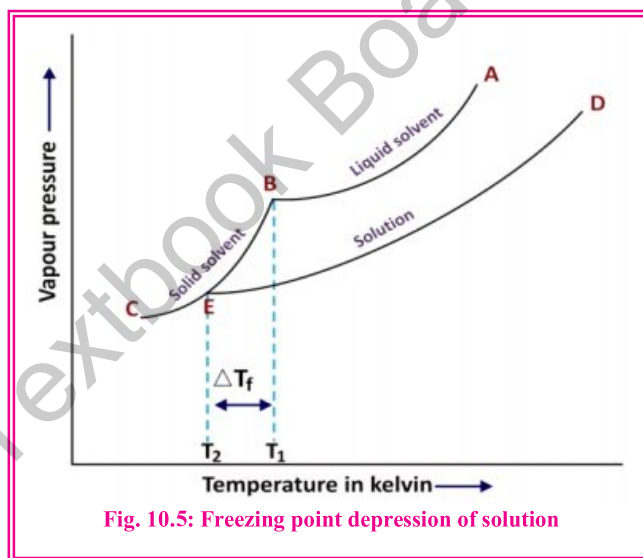


Fig. 10.5: Freezing point depression of solution

The presence of a non volatile solute lowers the freezing point of solvent. These phenomena can be explained in term of vapours pressure. Since at freezing point the vapours pressure of both liquid and solid phases must be same, the addition of solute causes a fall in vapours pressure. Thus in order to re-establish the equilibrium of two phases, temperature of solution is consequently lowered below the freezing point of pure solvent.



Do You Know?

While boiling an egg we often mix a small amount of table salt into water. This elevated the boiling point of solution and thus more heat is provided to the egg for its quick preparation.



10.4.3 Osmotic Pressure

Surface of certain materials permit water and other smaller size particles to pass through but do not allow large solute particles. These serves as semi permeable membrane for example cellophane, animal bladder etc. Although the passage of solvent particles takes place in both directions of semi permeable membrane but their movement is faster from dilute solution to concentrated solution. This spontaneous process is commonly known as osmosis. It is important to note that the process of osmosis remains continue until the concentration both solution become same.

To demonstrate the process of osmosis, let us consider a sugar solution is filled into an inverted thistle funnel whose mouth is covered with semi permeable membrane. The funnel is dipped into a beaker of pure water. As the time going on, water from the beaker migrate to the sugar solution through semi permeable membrane and hence rises up the level of solution in the funnel tube until the descending pressure exerted by the solution stops the passage of solvent particles from beaker to funnel, this is known as osmotic pressure and define as **“the hydrostatic pressure exerted by the solution which stops the process of osmosis”**.

Osmotic pressure is a colligative property since it depends upon the number of solute particles in the solution. It is represented by π and measured in atmosphere.

Daily life examples of Osmosis

- (i) Due to bacterial infection or certain other reasons, swelling and bursting of RBCs takes place in blood stream. This biochemical process is known as hemolysis. Literally, hemolysis is endo osmosis during which water pass through semi permeable membrane of RBCs and destroy them.
- (ii) Fresh water fish absorb water through their semi permeable skin because their body fluid is much saltier than the water in which they swim.
- (iii) Although plant absorbs water through their entire surface including root, leaves and stem, however it mainly occur by root hairs through the process of osmosis.



Do You Know?

When two solutions have equal osmotic pressure across a semi permeable membrane at the same temperature is referred as isotonic solution.

Isotonic saline solution keep cell from shrinking and swelling in our body.

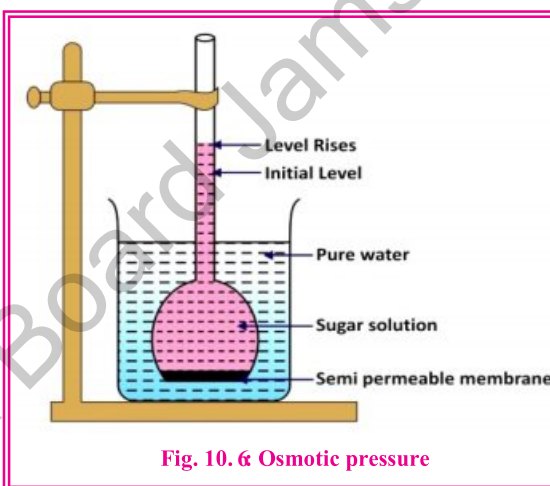


Fig. 10.6 Osmotic pressure



Do You Know?

To relief sore throat, we are often advised salt water gargling by doctors. Salt water contains high conc. of salt than fluid of the throat cells.

Therefore on gargling, the excess fluid passes out through osmosis and reduces the irritation or discomfort.



- (iv) Jam is prepared by adding high amount of sugar, while pickles are prepared by adding sufficient salt, oils, vinegar etc. These additives make the solution of Jam and pickles highly concentrated. Therefore water pass out from the semi permeable membrane of bacteria and other microorganism through the process of osmosis causing bacteria killing and avoid the chances of spoilage.
- (v) Food after digestion in various region of alimentary canal change into chyme which then absorb into body tissues through the semi permeable wall of small intestine.

10.5 COLLOIDS

Milk is a homogenous mixture of tiny particles of casein and some other ingredients in aqueous phase. These particles neither settle down like in suspension nor serves as solute of a solution. In chemistry they are known as colloidal dispersion or simply colloids. **“Colloids is a mixture in which one substance consisting of microscopically dispersed insoluble particles in suspended”** The size of colloidal particles is smaller than floating particles of suspension but larger than solute particles of solution. The size range of colloidal particle is from 1 to 1000nm. They cannot be seen by necked eye, never settle down in the container. However unlike solution they have ability to scatter light and this property is known as Tyndall effect.

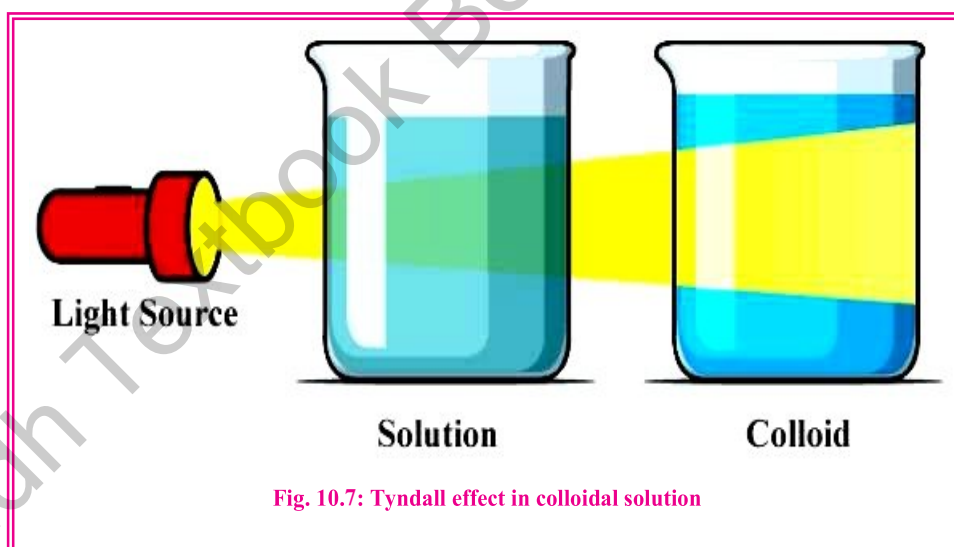


Fig. 10.7: Tyndall effect in colloidal solution

All those colloids in which water serves as dispersion medium are either hydrophilic or hydrophobic in nature. A hydrophilic colloid is that in which dispersed particles are strongly attracted by dispersion medium where as hydrophobic colloids shows lack of association of above type.

Colloids have a significant role in chemical industries, biochemical processes, agriculture and even in our daily life. Many of our food stuff are colloidal solution.



10.5.1 Types of Colloids

Colloids are classified into following eight types depending upon the physical state of dispersed phase and dispersion medium.

Dispersion Medium	Dispersed Material	Type of Colloid	Suitable Examples
Gas	Liquid	Aerosol	Fog, Spray
Gas	Solid	Aerosol	Smoke
Liquid	Gas	Foam	Shaving Cream
Liquid	Liquid	Emulsion	Milk
Liquid	Solid	Sol	Paint
Solid	Gas	Solid Foam	Foam Rubber
Solid	Liquid	Gel	Jelly
Solid	Solid	Solid Sol	Ruby Glass

10.5.2 Properties of Colloids

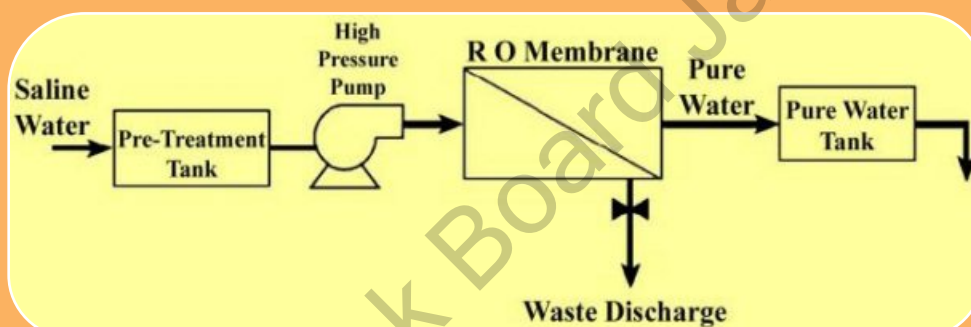
- (i) Colloidal solutions are heterogeneous in nature since they consist of two phases, the dispersed particles and dispersion medium. However they appear like a homogenous solution because of invisibility of suspended particles.
- (ii) Most of the colloidal solution exists in cloudy or translucent appearance.
- (iii) Colloidal particles can be seen under ultra microscope. The movement of colloidal particles is continuous, rapid and random like (Brownian motion). The reason of this type of motion is the unequal collision of colloidal particles with the particles of dispersion medium.
- (iv) Colloidal particles can pass through filter paper but semi permeable material block their movement across the membrane.
- (v) When a beam of visible light passes through a colloidal solution, it scattered by the colloidal particles and hence the whole path of the light beam becomes illuminates. This phenomenon is known as Tyndall effect.
- (vi) Coagulation is the process of precipitation of colloidal particles which can be accomplished by heating or by adding electrolyte. On heating, colloidal particles strike to each other many times with high energy and aggregate into each other to form large particle and thus settle out.
- (vii) Dispersed particles of colloidal solution possesses either positive or negative charge. However the charge of all dispersed particles remain the same that is why they repel each other and keep them self suspended in the dispersion medium instead of combining of form a large molecule. Electrophoresis the movement of colloidal particles towards particular electrode in an applied electric field



Society, Technology and Science

Concept of reverse osmosis in R.O plant

Reverse osmosis is a well known water purification technique in which sediments and contaminants of water are removed through semi permeable membrane and make the water drinkable. Reverse osmosis works on the basis of passage of water molecules across a semi permeable membrane from impure water to pure water by applying a high pressure which overcomes the osmotic pressure. In other words flow of water molecules takes places in reverse direction as carried out by natural osmosis. About 95 to 99 percent of the dissolved contaminant like salts, metal ions, protozoa etc are removed if water is processed by reverse osmosis.



Activity

The purpose of this activity is to enable you to prepare a solution of known strength (say one molar concentration of NaCl). In order to prepare one molar solution of sodium chloride, you need to dissolve one mole of NaCl in one liter solution. Since the molar mass of NaCl is 58.5g/mol. First of all you need to weigh one mole of NaCl on a digital balance of your kitchen by putting on salt bit by bit till the stage the digital balance exactly indicates its mass equal to 58.5g. Now take a volumetric flask filled with some water and start dissolving the salt in it. Then gently pour water to make the solution up to 1 liter mark. One molar NaCl solution is ready at your home.



SUMMARY with Key Terms

- ◆ **Solution** is a homogenous mixture of two or more substances. The component present in the larger amount is called solvent whereas the component which is in smaller amount is solute.
- ◆ **Dissolution** is the process of formation of a solution. This process is accompanied by heat absorption or evolution. This heat is called as heat of solution.
- ◆ **Hydrophilic molecules** are those which are evenly distributed throughout the water and form a homogenous mixture. This is due to their ability to attract with positive and negative terminals of water molecules.
- ◆ **Hydrophobic molecules** do not mix into water and do not form aqueous solution since they are non-polar in nature.
- ◆ **Miscibility** is the ability of a liquid to mix into another liquid.
- ◆ **Concentration** is the amount of solute dissolved in a fixed amount of solvent or solution. It expresses in terms of percentage composition, molarity, molality, mole fraction etc.
- ◆ **Raoult's Law** states that the vapour pressure of solution of non-volatile solute is directly proportional to the mole fraction of solvent.
- ◆ **Ideal solution** is that which perfectly obeys Raoult's law at all temperature and concentration. In the formation of ideal solution no heat is absorbed or evolved and no change in volume takes place.
- ◆ **Colligative properties** are certain physical properties of solution which depend upon the number of solute particles. These are lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure.
- ◆ **Molal elevation of boiling point (K_b)** is a constant and is defined as the elevation of boiling point of one molal solution.
- ◆ **Osmosis** is the spontaneous process of flow of solvent particles from higher concentration to lower concentration through a semi-permeable membrane.
- ◆ **Osmotic pressure** is the hydrostatic pressure exerted by solution which stops the further passage of solvent particles across the semi-permeable membrane.
- ◆ **Reverse Osmosis** is a water purification process through a membrane of tiny pores. It involves the flow of water molecules across the semi-permeable membrane in the opposite direction under high pressure. The purpose is to filter out salts and other large size particles from drinking water.
- ◆ **Colloidal solution** is a translucent solution of the particles of 1 nm to 1000 nm size. Its particles can only be seen by a powerful microscope however they coagulate on heating or adding an electrolyte.
- ◆ **Suspension** is an opaque, heterogeneous mixture of the particles of above 1000 nm size which settle down to their own.



EXERCISE

Multiple Choice Questions

1. Choose the correct answer

- (i) Only one pair of liquid in the following set does not obey Raoult law, identify it:
(a) Methanol and Ethanol (b) Benzene and toluene
(c) n-Hexane and n-heptane (d) Ethanol and Acetone
- (ii) Identify the incorrect statement about colloidal solution:
(a) It shows Tyndall effect (b) Its particles movement is Brownian type
(c) Its particle size is less than 1 nm (d) Its physical appearance is translucent
- (iii) Effect of pressure change play significant role in the solubility of:
(a) Solid into liquid (b) Liquid into liquid
(c) Gas into liquid (d) All of them
- (iv) Which is not a colligative property:
(a) Lowering in vapours pressure (b) Elevation in boiling point
(c) Depression in freezing point (d) Atmospheric pressure
- (v) According to Raoult law the relative lowering of vapour pressure is equal to:
(a) Mole fraction of solvent (b) Mole fraction of solute
(c) Molality (d) Molarity
- (vi) The sum of mole fractions of components of a solution is equal to:
(a) 0.0 (b) 1.0
(c) 10 (d) 100
- (vii) How many moles of NaOH are present in a 2dm^3 of 1 molar aqueous solution of it.
(a) 0.5 mole (b) 1 mole
(c) 1.5 mole (d) 2 mole
- (viii) A colloidal solution of liquid into liquid is known as:
(a) Gel (b) Foam
(c) Sol (d) Emulsion
- (ix) An example of completely immiscible liquid pair is:
(a) Benzene to toluene (b) Water and phenol
(c) Water and Benzene (d) Water and methanol
- (x) A 15% W/W KOH solution can be prepared by mixing 15g KOH in:
(a) 15g water (b) 85g water
(c) 100g water (d) 115g water



Short Questions

1. Name various units of concentration and explain mole fraction.
2. Define Molarity and molality. Which of these depends on temperature?
3. Explain on particles bases how the vapours pressure of solution is lowered by adding non volatile solute.
4. What are miscible and immiscible liquids? Why n-hexane (petrol) is immiscible in water?
5. Solubility of oxygen in water increases with pressure but solubility of glucose in water has negligible effect of pressure why?

Descriptive Questions

1. State Raoult's law and derive its mathematical expression.
2. What does an Ideal solution means? Give four characteristics to distinguish between ideal and non ideal solution.
3. Define osmosis and osmotic pressure. Give four daily life examples of osmosis.
4. What are colligative properties? Why does the boiling point of a liquid get raised when a non volatile solute is added?
5. Differentiate among true solution, colloidal solution and suspension on the bases of.
(i) Particle size (ii) Visibility

Numerical Questions

1. Automotive antifreeze is a 60% (w/w) aqueous solution of ethylene glycol ($C_2H_6O_2$). Determine (a) molality of solution (b) mole fraction of ethylene glycol in the solution.
[Ans: molality = 24.19mol/kg, X = 0.3]
2. A solution is prepared by mixing 46g ethanol (C_2H_5OH) and 180g water. Calculate the mole fraction of both components. [Ans: $X_2 = 0.090$, $X_1 = 0.909$]