CHAPTER-7

SOLUTION AND SUSPENSION

You will learn in this chapter about:

- * Solution.
- * Types of solution.
- * Saturated, unsaturated and super saturated solutions.
- * Factors affecting solubility.
- * Crystallization.
- * Strength of a solution.
- * Suspension.
- * Examples of suspensions in daily life.

7.1 SOLUTION

A soulution is defined as a homogeneous mixture of two or more substances. The relative amounts of the components can be gradually changed within certain limits. The component of solution present in smaller amount is called **solute**, whereas the component present in greater quantity is called **solvent**. For example in a 5% glucose solution in water, solute is glucose and solvent is water. When water is solvent the solution is called **aqueous solution.**

Types of Solution:

Since matter exists in three states i.e. solid, liquid and gas, on mixing they produce nine types of solutions, which are listed as following:

Table.

No.	Solute	Solvent	Examples
1.	Gas	Gas	Air (Mixture of 78% N_2, 21% O_2 and 1% other gases)
2.	Gas	Liquid	Carbonated soft drinks such as coca-cola, Bubble-up etc. NH_3gas in water, and air dissolved in water.
3.	Gas	Solid	H_2 gas adsorbed over palladium metal
4.	Liquid	Gas	Cloud (water vapours in air), steam.
5.	Liquid	Liquid	Alcohol in water, water in milk, milk in tea, vinegar (acetic acid in water)
6.	Liquid	Solid	Amalgam (e.g. Mercury in sodium), and water in jelly powder.
7.	Solid	Gas	Smoke (carbon particles in air),
8.	Solid	Liquid	Sugar in water, sea water
9.	Solid	Solid	Alloys such as brass (copper and zinc) bronze (copper and tin), steel (carbon and iron), glass.

7.2 FACTORS AFFECTING SOLUBILITY

Many factors affect the solubility of a solute in a solvent. These factors may be:

1. Temperature.
2. Pressure (For gases).
3. Nature of solute.
4. Nature of solvent

Solubility and Temperature:

Solubility of a solid in liquid or solubility of partially miscible liquids increases with increase in temperature. Thus solubility of sugar in water at 0°C is 179 g/100ml whereas at 100°C it is 487 g / 100 ml.

But the solubility of gases in a liquid decreases with the increase in temperature. For this reason when a glass of cold water is warmed, bubbles of air are seen on the inside of the glass.

Solubility and Pressure:

The solubilities of solids and liquids are not affected by pressure. But the solubility of a gas in a liquid is directly proportional to the pressure of gas. This is called **Henry's Law** i.e.

$$m \propto P \text{ or } m = KP$$

Where "m" is the amount of gas dissolved.

This effect is used in manufacture of bottled soft-drinks as coca-cola; 7-up etc. These are bottled under a CO_2 pressure slightly greater than 1 atm. When the bottles are opened, pressure decreases, so solubility of CO_2 also decreases, hence bubbles of CO_2 come out of solution.

Solubility and Nature of Solute and Solvent:

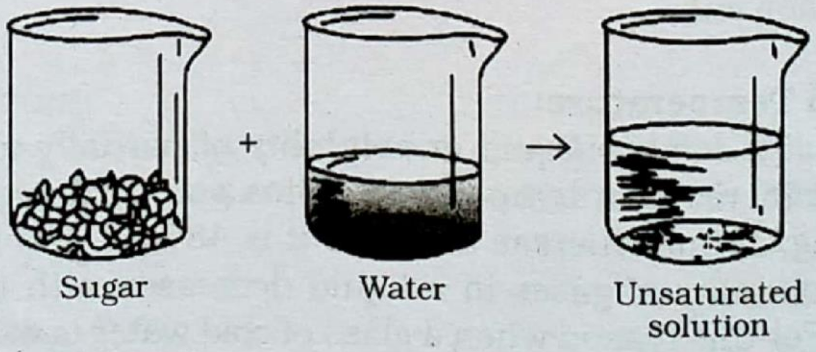
Solute and solvent may be polar (as H_2O; Alcohol) and non-polar (as benzene, carbontetrachloride). Polar and ionic solutes easily dissolve in polar solvents whereas non-polar solute easily dissolve in non-polar solvents. Hence it is said that **like dissolves like**. For example common salt (NaCl) being an ionic compound easily dissolves in polar solvent like water but is insoluble in non-polar solvent like benzene or petrol.

7.3 UNSATURATED, SATURATED AND SUPER SATURATED SOLUTIONS:

An unsaturated solution is that one which contains less solute than it has the capacity to dissolve. If more solute is added, at least some of it will dissolve.

Preparation of unsaturated solution:

Take a few crystals of sugar and dissolve them in a glass of water. This results in an unsaturated solution, because the solution has a capacity to dissolve more crystals of sugar (solute) at a given temperature.

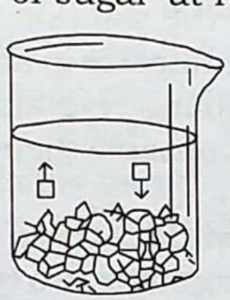


A saturated solution is that one which contains maximum amount of solute in a given solvent at room temperature. No more solute can dissolve in it and there is a dynamic equilibrium between the undissolved and dissolved solute. This type of solution is called saturated solution.

The amount in grams of a solute required to be dissolved in 100 grams or 100 ml of a solvent to prepare a saturated solution at room temperature is called **solubility** of that solute, expressed in g/ 100 ml or g/ 100 g at that specific temperature.

Preparation of a Saturated Solution:

Take some water in a beaker. With constant stirring, add crystals of sugar till they do not dissolve and start to settle down. The solution thus obtained is saturated solution of sugar at room temperature.



A super saturated solution is that which contains greater amount of dissolved solute than that present in a saturated solution at the given temperature. Preparation of super saturated solution is required for crystallization. Crystallizaiton is simple and general technique for purification of impure compounds.

7.4 CRYSTALLIZATION

Crystals are homogeneous solids, having regular and definite geometrical shape with faces and sharp edges. Pure crystals of compounds have sharp melting points.

When a super saturated solution of a solid is prepared at high temperature and allowed to cool down, then at lower temperature it cannot hold more solute in dissolved state. Some of these dissolved solute particles come out of solution in solid form having regular and definite geometric shapes. They are called crystals. The process in which dissolved solute comes out of solution and forms crystals is called **crystallization**.

Following are two practical examples of super saturated solution preparation and crystallization.

Preparation of Crystals of Copper Sulphate (Blue Vitriol $CuSO_4.5H_2O$)

Prepare a saturated solution of copper sulphate in water at room temperature using a beaker. Heat the saturated solution and try to dissolve some more quantity of copper sulphate while stirring the solution with glass rod. Allow the super saturated solution of copper sulphate to cool down at room temperature. Upon cooling and standing, crystals of $CuSO_4.5H_2O$, i.e., blue vitriol will form. Filter out the crystals and observe the shape of crystals under a light microscope.

Preparation of Crystals of Potassium Nitrate (KNO_3)

Take 100 ml water in a beaker. Prepare a saturated solution of KNO_3 by dissolving 37g of solute at room temperature by means of stirring with glass rod. Now heat this saturated solution to 50°C and dissolve 20g of additional KNO_3 while stirring the solution. Filter the hot super saturated solution quickly and collect the filterate in another beaker. Cool the filterate to room temperature. Upon cooling crystals of KNO_3 are formed.

Filter out the crystals and observe their shape under light microscope.

Purification of Solids by Crystallization:

An impure solid generally contains two types of impurities. An insoluble impurity and a soluble impurity. Insoluble impurity is totally insoluble in the solvent used for crystallization even at boiling temperature. While the soluble impurity remains in soluble form at room temperature. Therefore, a compound containing such two types of impurities could be easily removed by means of crystallization technique.

For example, a 42g impure sample of KNO_3 contains a small quantity of sand and NaCI. To obtain pure crystalline KNO_3, we perform the crystallization technique as follows:

Take 50ml of water in a beaker and add the impure sample (40g) of KNO_3 to it while stirring with glass rod. Supply heat gently till the temperature of the solution is above 50°C. Stir the solution at this temperature till most of the solid is dissolved. Filter the hot solution and collect the filtrate in a beaker. Sand being insoluble in water will be removed and collected on the filter paper. Upon cooling of the filtrate, crystals of KNO_3 will start appearing. When no further crystals are formed, filter it again and collect the filtrate in a beaker. Purified crystals of KNO_3 are obtained on the filter paper. The filtrate will contain some quantity of the dissolved KNO_3 along with the NaCl, being a soluble impurity.

7.5 STRENGTHS OF A SOLUTION

The strength (concentration) of a solution means the mass or volume of the solute present in known amount of solvent or solution.

The following are the common methods of expressing the strength (concentration) of a solution.

1. Molarity (M)
2. Molality (m)
3. Mole fraction (x)
4. Percentage (%)
5. Normality (N). It is not used in these days.

1. Molarity (M):

It is defined as *the number of moles of solute dissolved in 1 liter ($1dm^3$) of a solution, it is denoted by (M).*

Thus, 1 mole of NaOH (i.e its gram formula mass) 40g dissolved in 1 litre ($1dm^3$) of solution is said to be 1 molar (1M) solution. If only half of the mole i.e 20g of NaOH is dissolved in one litre ($1dm^3$) of solution, the solution is said to be one-half molar (i.e. 0.5M)

The molarity of any solution is found by dividing the number of moles of solute by the number of liters of solution.

$$\text{Molarity (M)} = \frac{\text{Moles of solute}}{\text{Litres of solution or dm}^3\text{ of solution}}$$

We know that:

(i) $$\text{Number of moles} = \frac{\text{Given mass of solute}}{\text{Gram formula mass of solute}}$$

(ii) $$\text{Litres of solution} = \frac{\text{mls of solution}}{1000}$$

Thus,

$$\text{Molarity= (M)} = \frac{\text{Mass of solute}}{\text{Gram formula mass of solute}} \times \frac{1000\text{ cm}^3\text{ (ml)}}{\text{ml (cm}^3\text{) of solution}}$$

For example:

Calculate the molarity of a solution containing 4g of NaOH in 500 cm^3 (ml) of solution?

Solution:

$$M = \frac{\text{Mass of solute } \times 1000\ cm^3}{\text{Gram formula mass } \times cm^3 \text{ of solution}}$$

Data:

i)	Molarity (M)	=	?
ii)	Mass of solute NaOH	=	4g
iii)	Gram formula mass of solute	=	40g
iv)	cm^3 of solution	=	$500cm^3$

$$\therefore M = \frac{4g \times 1000\ cm^3}{40\,g \times 500cm^3} = \frac{1}{5} = 0.2M$$

Result: Molarity (M) = 0.2M

2. **Molality (m):**

It is defined as *the number of moles of solute dissolved per 1000g (1kg) of solvent, it is denoted by (m).*

Thus 1mole of Na_2CO_3 (i.e. its gram formula mass) 106g dissolved in 1000g of solvent is said to be 1 molal (1m) solution.If only half of the mole i.e. 53g of Na_2CO_3 is dissolved in 1000g of solvent, the solution is said to be one-half molal (i.e. 0.5m)

The molality of a solution is found by the following formula.

$$\text{Molality (m)} = \frac{\text{Mass of solute} \times 1000g}{\text{Gram formula mass} \times \text{grams of solvent}} \text{ or } \frac{\text{No of moles of solute}}{\text{Kg of the solvent}}$$

For example:

Calculate the molality of solution containing 5.3g of Na_2CO_3 in 500g of water.

Solution:

$$\text{Molality (m)} = \frac{\text{Mass of solute} \times 1000g}{\text{Gram formula mass of solute} \times \text{grams of solvent}}$$

Data:

1.	Molality = (m)	=	?
2.	Mass of solute i.e. Na_2CO_3	=	5.3g
3.	Gram formula mass of solute Na_2CO_3	=	106g
4.	Grams of solvent (water)	=	500g

$$\text{Molality} = m = \frac{\text{Mass of solute} \times 1000g}{\text{Gram formula mass of solute} \times \text{grams of solvent}}$$

$$m = \frac{5.3g \times 1000g}{106g \times 500g} = \frac{1}{10} = 0.1m$$

Result: Molality = 0.1m

3. Mole fraction (X):

Mole fraction (X) of any component in a solution is the number of moles of the component divided by total number of moles making up a solution. It is denoted by X.

$$\text{Mole fraction (X)} = \frac{\text{Moles of component}}{\text{Total number of moles making up solution}}$$

For example, a solution is prepared by dissolving 1 mole of ethyl alcohol C_2H_5-OH in 3 moles of water (H_2O), where n_A and n_B represent the number of moles of ethyl alcohol and water respectively.

Then

$$\text{Mole fraction of ethyl alcohol} = X_A = \frac{n_A}{n_A + n_B} = \frac{1}{1+3} = \frac{1}{4} = 0.25$$

$$\text{Mole fraction of water} = X_B = \frac{n_B}{n_A + n_B} = \frac{3}{1+3} = \frac{3}{4} = 0.75$$

Result: Mole fraction of ethyl alcohol $X_A = 0.25$

Mole fraction of water $X_B = 0.75$

Note, that sum of the mole fractions is equal to 1.

Mole fraction of ethyl alcohol = 0.25

Mole fraction of water = 0.75

Sum of the mole fractions = 1.00

Remember

The mole fraction is dimensionless quantity that expresses the ratio of the number of moles of one component to the number of moles of all components present. The sum of mole fractions of all components of a solution must equal 1

4. Percentage (%):

This is based on mass (m) or volume (v) of components of solution. It is of four types.

i) Percentage in $\frac{M}{M}$ $\left(\frac{mass}{mass}\%\right)$

ii) Percentage in $\frac{M}{V}$ $\left(\frac{mass}{vol}\%\right)$

iii) Percentage in $\frac{V}{M}$ $\left(\frac{vol}{mass}\%\right)$

iv) Percentage in $\frac{V}{V}$ $\left(\frac{vol}{vol}\%\right)$

Examples:

(i) 5% (M/M) solution means solute 5g in 95gm solvent.
(ii) 10% (M/V) solution means solute 10g in solution 100cm^3.
(iii) 5% (V/M) solution means solute 5cm^3 in solution 100 g.
(iv) 15% (V/V) solution means solute 15 cm^3 in 85 cm^3 solvent.

Problem of %:

6.5g of NaCl are dissolved in 43.5 g water. Calculate the percent by mass of NaCl in this solution.

Solution:

$$\text{\% by mass of solute NaCl} = \frac{\text{Mass of solute} \times 100}{\text{Mass of solute + Mass of solvent}}$$

$$= \frac{6.5 \times 100}{6.5 + 43.5} = \frac{6.5 \times 100}{50.0}$$

Percent by Mass of NaCl = 13.0 %

7.6 SUSPENSION

If sugar or salt is dissolved in water, the crystals dissolve into molecules or ions. The resulting homogenous mixture is called true solution. If a fine sand is stirred in water, the crystals do not dissolve, but even after several days some of the smallest particles remain suspended, such mixture is called a **suspension.**

Suspension is defined as *a hetrogenous mixture consists of visible particles, each of which contains many thousands or even millions of molecules, surrounded by molecules of liquid.*

> ***Important to note***
>
> *Homogenous mixtures can be classified according to size of the constituent particles, as solution, suspension or colloids. In solution the dispersed partilces are of molecular size (0.1-1nm). In suspension, the dispersed particles are much larger than molecules (>1000nm).*
>
> *Between these two extreme type of dispersion, there is another type of homogenous mixture in which dispersed particles are larger than molecules (2.0-1000 nm) but not large enough to settle out. This intermediate type of mixture is called colloid.*

Difference Between Solution and Suspension

Solution	Suspension
1. The size of particles is between 0.1 to 1nm.	1. The size of particles is larger than 1000 nm.
2. Particles cannot be seen with low power microscope.	2. Particles can be seen by low power microscope.
3. It is homogeneous.	3. It is heterogeneous.
4. Particles do not settle down.	4. Particles settle down.
5. It is transparent.	5. It is not transparent.
6. Components cannot be separated by filtration.	6. components can be separated by filtration.

Examples of Suspensions in Daily Life:

1) **Smoke:** A suspension of the particles of carbon in a gas or air.
2) **Mud (slime):** A suspension of fine particles of solid in small quantity of liquid.
3) **Foam (froth):** A suspensionof fine particles of a gas in a liquid.
4) **Emulsion:** A suspension of droplets of one liquid into another in which it is not soluble.

SUMMARY

1. A homogenous mixture of two or more substances with uniform composition is called solution. A solution has two components, solute and solvent.
   A solute is the substance which is dissolved and is in smaller quantity while a solvent is the substance in which a solute is dissolved and is in larger quantity.
2. There are nine types of solutions depending upon the nature of solute and solvent. If solvent is liquid then the solution is considered as true solution.

3. A solution in which the amount of the solute is less than it has the capacity to dissolve in large quantity of solvent is called unsaturated solution.

The solution which contains maximum amount of solute in a given solvent at a specific temperature and no more solute dissolves in it is called saturated solution. In a saturated solution there is a dynamic equilibrium between dissolved and undissolved solute.

4. A super saturated solution contains greater amount of dissolved solute than that are peresent in a saturated solution. It is obtained by dissolving solute in saturated solution on heating. More solute would dissolve on heating saturated solution.

5. The solubility is defined as the amount of solute in gram dissolved at a given temperature in 100 gram of the solvent. Many factors affect the solubility of a solute in a solvent which are temperature, pressure (for gases), nature of solute and solvent. Generally the solubility of a solute increases with the rise in temperature except gases whose solubility decreases with the rise in temperature.

The solubility of gases in a solvent is generally less, but the solubility of gases increases with increase in pressure and is directly proportional to pressure applied. It is governed by Henry's Law.

Nature of solute and solvent also affects on the solubility. It is well known fact that **like dissolves like.**

6. Crystallization is the process in which dissolved solute comes out of the solution and forms crystals. Crystals are homogenous solids bounded by plane faces, having sharp edges, regular and definite shapes. They have sharp melting points. Crystallization may occur by the process of evaporation or by cooling heated solution.

7. In a solution the amount of solute dissolved in a given quantity of solvent is known by its concentration. The solution that contains less amount of solute as compared to the amount of solvent is known as "dilute solution" and the solution that contains greater amount of solute as compared to the amount of the solvent is known as "concentrated solution".

8. The different units in which the concentrations of the solutions are expressed are molarity, molality, mole fractions, percent concentrations.

Molarity is defined as the number of moles of the solute, dissolved per dm^3 or litre of the solution. It is denoted by M.

Molality is defined as the number of moles of the solute, dissolved in per kg or 1000 gram of the solvent. It is denoted by m.

Mole fraction is defined as the ratio of moles of solute or solvent to the total moles of the solution. It is denoted by X.

For example

$$X_{solute} = \frac{\text{No. of moles of solute}}{\text{Total moles of solute and solvent in the solution}}$$

Percent concentration is based on mass (M) and volume (V) of the components solute and solvent in the solution. There are four different ways in which percent concentration can be expressed.

$$\%\frac{M}{M};\quad \%\frac{M}{V};\quad \%\frac{V}{M};\quad \text{and}\quad \%\frac{V}{V}$$

9. A suspension is a mixture in which particles are of one or more substances having size larger than 1000 nanometer (n.m) (1000 n.m or 1000 x10^{-9}m). In suspension the solute particles are not soluble in solvent and can be removed by filteration because the solute particles are big enough not to pass from the pores of filter papers. Suspension is heterogenous.

EXERCISE

1. Fill in the blanks:

(i) Solution is a .... of two or more substances.

(ii) The most common solvent in nature is ....

(iii) An .... is the solution when the liquid solvent is water.

(iv) 10%$\frac{M}{M}$ solution contains 10 gram solute, dissolved in ......g solvent.

(v) .... is the symbol for the concentration unit of molarity.

2. Tick the correct answer:

(i) The suspended particles in suspensions are generally of the size.

(a) 10nm (b) 100nm
(c) 1200nm (d) 1nm

(ii) The sum of the mole fractions of solute and solvent is equal to:
(a) 5 (b) 2
(c) 0 (d) 1

(iii) Solubility is defined as the amount of solute in gram at a given temperature, dissolved in .... of the solvent.
(a) 20g (b) 100g
(c) 10g (d) 2000g

(iv) The process in which a solid directly changes to vapours is known as:
(a) Sublimation (b) Evaporation
(c) Diffusion (d) Fusion

(v) The solubility of a gas .... with the rise in temperature.
(a) Increase (b) Decrease

3. Tick true or false:

(i) The process of converting a solid into liquid at its melting point is called fusion.
(ii) A suspension is a homogenous mixture of two or more substances.
(iii) The solution that contains maximum amount of solute in a given solvent at specific temperature is a saturated solution.
(iv) Crystals have irregular geometrical shape.
(v) Smoke is a suspension of carbon particles in air.

4. Write answer of the following questions:

(i) Define the following terms:
(a) Solute (b) Solvent
(c) Solubility (d) Crystallization

(ii) Name the solute and solvent in the following solutions:
(a) Syrup (b) Haze (Dust in air)
(c) Butter (Water in fat) (d) Fog
(e) Jellies (Water in fruit pulp) (f) Smoke
(g) Sodium amalgam (h) Cheese (Water in fat)
(i) Foam (Water in air) (j) Mist

(iii) Discuss the factors affecting the solubility.

(iv) Explain Why?

 (a) Common salt dissolves in water but not in petrol.

 (b) Cold drinks are bottled under a CO_2 pressure greater than 1 atmosphare.

 (c) 100 ml solution of KNO_3 can not hold more than 37gm of KNO_3 in dissolved state.

(v) Calculate molarity of solution containing 16 gm glucose per 300 ml solution.

(vi) Find the mass of sucrose (Molecular Mass=342) required to be dissolved per 600cm^3 solution to prepare a semi-molar solution.

(vii) 5.3 gm Na_2 CO_3 was dissolved in 800gm water, calculate the molality of solution.

(viii) It is desired to prepare 3 molal solution of NaOH. How much mass of it must be dissolved in 1500gm water.

(ix) Differentiate between (a) Saturated and unsaturated solution, (b) Solution and suspension.