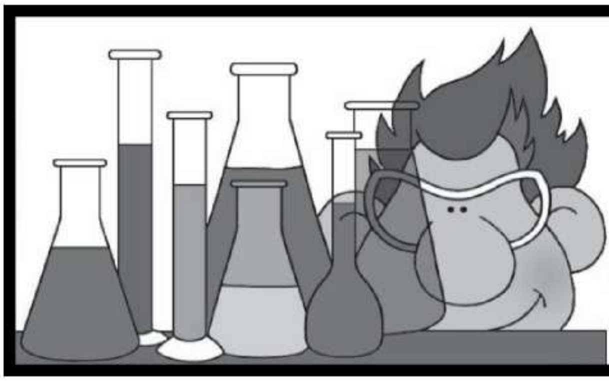


CHAPTER 6
SOLUTIONS

SUBJECTIVE PART

LONG QUESTION ANSWERS

Introduction

Solutions:
Solutions are homogeneous mixtures of two or more components.

Physical states of solutions:
Generally, solutions are found in three physical states depending upon the physical state of the solvent, e.g.

- Alloy is a solid solution;
- sea water is a liquid solution
- Air is a gaseous solution.

Types of solutions:
There are nine types of solutions ranging from gas-gas e.g. air we breathe to solid-solid solutions e.g. dental amalgam for filling of tooth.

Most common solutions:
Liquid solutions are the most common solutions because of the most common solvent water. Therefore, there is a wide variety of liquid solutions ranging from a drop of rain to oceans. Sea water is a resource of 92 naturally occurring elements.

6.1 Solutions

Q:1 Explain the term solution with the help of examples.

Ans: Solution:

"A homogeneous mixture of two or more substances is called solution."

Solute + Solvent = Solution

Examples:

i. Sugar solution
ii. Sodium chloride solution
iii. Copper sulphate solution
iv. Air
v. Brass
vi. Sea water

Physical states of solutions:

i. Solid: e.g. alloy
ii. Liquid: e.g. sea water
iii. Gas: e.g. air

Properties of a solution:

i. A solution has only one phase
ii. A solution is usually named after the name of solute

iii. The physical state of solution is the same as that of solvent
iv. It shows the properties of its components
v. It has a uniform composition
vi. It is transparent though it may be coloured
vii. It is electrically neutral

Homogeneous mixture:

"A mixture having uniform composition throughout is called homogeneous mixture."

The boundaries of the components can't be distinguished i.e. a solution exist as one phase.

Example:

i. The air we breathe is a solution of several gases.
ii. Brass is a solid solution of Zn and Cu.
iii. Sugar dissolved in water.

Q:2 Define the terms.

i. Aqueous solution **ii. Universal solvent** **iii. Solute**
iv. Solvent

Ans: i. Aqueous Solution

"The solution which is formed by dissolving a substance in water is called an aqueous solution."

In aqueous solutions water is always present in greater amount and termed as solvent Water is called a universal solvent because it dissolves majority of compounds present in earth's crust.

Examples:

i. Sugar in water.
ii. Table salt in water.

Distinguish between solution & pure liquid:

i. The simplest way to distinguish between a solution and a pure liquid is evaporation.
ii. The liquid which evaporates completely, leaving no residue, is a pure compound,.
iii. While a liquid which leaves behind a residue on evaporation is solution.
iv. An alloy like brass or bronze is also a homogeneous mixture.
v. Although it cannot be separated by physical means.
vi. It shows the properties of its components and
vii. It has a variable composition.

ii. Universal solvent:

"Water is called a universal solvent because it dissolves majority of compounds present in earth's crust."

Water can dissolve ionic as well as covalent compounds e.g NaCl, Cl_2, HCl

iii. Solute:

"The component of solution which is present in smaller quantity is called solute".

Examples:

A solute is dissolved in a solvent to make a solution in sugar. In sugar solution, sugar is solute and in sodium chloride solution, sodium chloride is solute.

Number of solutes present in a solution:

In a solution if more than two substances are present, one substance acts as solvent and others behave as solutes

Example:

In soft drinks, water is solvent while other substances like sugar, salts and CO_2 are solutes.

iv. Solvent:

"The component of a solution which is present in larger quantity is called solvent."

Example:

In soft drinks, water is solvent while other substances like sugar, salts and CO_2 are solutes.

Q:3 Explain saturated, unsaturated solution and super saturated solutions with the help of examples.

Ans: i. Saturated Solution:

"A solution containing maximum amount of solute at a given temperature is called saturated solution"

$$\text{Solute (crystallized)} \rightleftharpoons \text{Solute (dissolved)}$$

Preparation of saturated solution:

When a small amount of solute is added in a solvent, solute dissolves very easily in solvent. If the addition of solute is kept on, a stage is reached when solvent cannot dissolve more solute. At this stage, further added solute remains un-dissolved and it settles down at the bottom of the container.

Dynamic equilibrium in saturated solution:

On the particle level, a saturated solution is the one, in which un-dissolved solute is in equilibrium with dissolved solute.

$$\textit{Solute (crystallized)} \rightleftharpoons \textit{Solute (dissolved)}$$

At this stage dynamic equilibrium is established. Although dissolution and crystallization continues at a given temperature, but the net amount of dissolved solute remains constant.

$$\textit{Solute} + \textit{Solvent} \underset{Crystallize}{\overset{Crystallize}{\rightleftharpoons}} \textit{Solution}$$

ii. Unsaturated Solution:

"A solution which contains lesser amount of solute than that which is required to saturate it at a given temperature, is called unsaturated solution".

Such solutions have the capacity to dissolve more solute to become a saturated solution.

Example:

1dm^3 of NaCl solution in which 3g of NaCl are dissolved

iii. Super saturated solution:

"The solution that is more concentrated than a saturated solution is known as supersaturated solution".

Preparation of Supersaturated Solution:

When saturated solutions are heated, they develop further capacity to dissolve more solute. Such solutions contain greater amount of solute than is required to form a saturated solution and they become more concentrated. Super- saturated solutions are not stable. Therefore, an easy way to get a supersaturated solution is to prepare a saturated solution at high temperature. It is then cooled to a temperature where excess solute crystallizes out and leaves behind a saturated solution.

Example:

A saturated solution of sodium thiosulphate ($Na_2S_2O_3$) in water at 20 ^oC has 20.9 g of salt per 100 cm^3 of water. Less than this amount of salt per 100 cm^3 of water at 20 ^0C will be an unsaturated solution. A solution having more amount than 20.9 g of salt per 100 cm^{3}of water at20 ^0C will be a supersaturated solution.

Q:4 Differentiate between dilute and concentrated solutions with a common example.

Ans: Dilute solutions:

Dilute solutions are those which contain relatively small amount of dissolved solute in the solution.

Example:

A solution containing 5g of sodium chloride in 100g water is a dilute solution.

Concentrated solutions:

Concentrated solutions are those which contain relatively large amount of dissolved solute in the solution.

Example

i. Brine is a concentrated solution of common salt in water. Addition of more solvent will dilute the solution and its concentration decreases.

ii. 0.1M Na_2CO_3 solution is dilute solution as compared to 5M Na_2CO_3 solution.

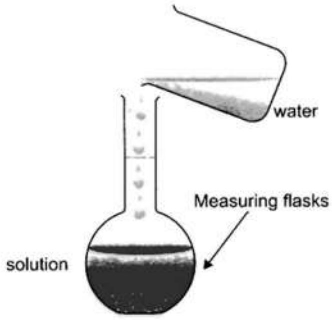


Fig. 6.1 Dilution of a solution.

Explain different types of solution with examples.

Ans: Solution:

A homogeneous mixture of two or more substances is called a solution

Examples: Sugar solution, Air etc

Types of Solutions:

Each solution consists of two components, solute and solvent. The solute as well as solvent may exist as gas, liquid or solid. There are nine types of solutions depending upon the physical state of solute and solvent.

Table: Different types of solutions with examples

Sr. No	Solute	Solvent	Example of Solutions
1	Gas	Gas	Air, mixture of H_2 and He in weather balloons, mixture of N_2 and O_2 in cylinders for respiration.
2	Gas	Liquid	Oxygen in water, carbon dioxide in water.
3	Gas	Solid	Hydrogen adsorbed on palladium.
4	Liquid	Gas	Mist, fog, liquid air pollutants.
5	Liquid	Liquid	Alcohol in water, benzene and toluene.
6	Liquid	Solid	Butter, cheese.
7	Solid	Gas	Dust particles or smoke in air.
8	Solid	Liquid	Sugar in water.
9	Solid	Solid	Metal alloys such as brass (Cu + Zn), bronze (Cu + Sn), opals etc

Q:5 Write down the types and properties of concentration units for solution.

Ans: Concentration Units:

Concentration:

The proportion of a solute in a solution is called concentration.

OR

It is also a ratio of amount of solute to the amount of solution or ratio of amount of solute to amount of solvent is called concentration of solution.

$$\text{Concentration of solution} = \frac{\text{Amount of solute}}{\text{Amount of solution or amount of solvent}}$$

Independence of Concentration:

Concentration does not depend upon the total volume or total amount of the solution.

Example:

A sample taken from the bulk solution will have the same concentration.

Concentration Units:

There are various types of units used to express concentration of solutions.

Percentage:

The number of parts of a component present in 100 parts of a substance is called percentage or percentage composition.

Percentage unit of concentration refers to the percentage of solute present in a solution. The percentage of solute can be expressed by mass or by volume. It can be expressed in terms of percentage composition by four different ways.

i. Percentage mass / mass (%m/m):

"It is the number of grams of solute in 100 grams of solution."

Example:

10%m/m sugar solution means that 10g of sugar is dissolved in 90g of water to make 100g of solution.

$$\%m/m = \frac{\text{Mass of solute (g)}}{\text{Mass of solution (g)}} \times 100$$

ii. Percentage - mass/volume (%m/v):

It is the number of grams of solute dissolved in 100 cm^3 of solution.

Example:

10 % m/v sugar solution contains 10 g of sugar in 100 cm^3 of solution. The exact volume of solvent is not mentioned or it is not known.

$$\%m/v = \frac{\text{Mass of solute (g)}}{\text{Volume of solution }(cm^3)} \times 100$$

iii. Percentage - volume/mass (%v/m)

It is the volume in cm^3 of a solute dissolved in 100 g of the solution.

Example:

For example, 10 % alcohol solution in water means 10 cm^3 of alcohol is dissolved in (unknown) volume of water so that the total weight of solution is 100 g. In such solutions the mass of solution is under consideration, total volume of the solution is not considered.

$$\%m/v = \frac{\text{Volume of solute }(cm^3)}{\text{Mass of solution (g)}} \times 100$$

iv. Percentage – volume/volume (% v/v)

It is the volume in cm^3 of a solute dissolved per 100 cm^3 of the solution".

Example:

30 percent v/v alcohol solution means 30 cm^3 of alcohol dissolved in sufficient amount

Formula:

$$(\%v/v) = \frac{\text{Volume of solute}(cm^3)}{\text{Volume of solution}(cm^3)} \times 100$$

Q:6 What is molarity and give its formula to prepare molar solution?

Ans: Molarity

Number of moles of solute dissolved in one dm^3 of solution is called molarity. It is *represented by M.*

Significance:

It is a concentration unit. The formula used for preparation of molar solution is as follows. molarity is the unit mathly used in chemistry and allied silences.

Formula:

$$\text{Molarity} = \frac{\text{Mass of solute}}{\text{Molar mass of solute}} \times \frac{1000}{\text{Volume of solution in cm}^3}$$

$$\text{Molarity (M)} = \frac{\text{No of moles of solute}}{\text{Volume of solution } (\text{dm}^3)}$$

Units of Molarity:

$$\text{Molarity} = \frac{\text{No of moles of solute}}{\text{Volume of solution in dm}^3}$$

$$M = \frac{\text{Mol}}{\text{dm}^3}$$

$$M = \text{Moldm}^{-3}$$

Preparation of Molar Solution:

A solution which contains 1mole of solute dissolved per dm^3 of solution is called molar solution.

One Molar solution is prepared by dissolving 1 mole (molar mass) of the solute in sufficient amount of water to make the total volume of the solution up to $1dm^3$ in a measuring flask.

Example:

1M solution of NaOH is prepared by dissolving 40g of NaOH in sufficient water to make the total volume $1dm^3$•

Relationship between solute and molarity:

Solute $\propto$ molarity

As amount of solute is increased, its concentration or molarity also increases. 2M solution is more concentrated than 1M solution.

Q:7 Explain how dilute solution are prepared from concentrated. OR Explain dilution of solution in detail.

Ans: Dilution of Solution:

The process of decreasing concentration of solution by a adding more solvent in it is called dilution of solution.

Example:

We do have 2M solution of NaCl. If we add more solvent (water) to it, the concentration of solution decreases. This process is called dilution of solution. Dilute molar solution is prepared from a concentrated solution of known molarity.

Example:

Suppose we are to make $100cm^3$ of 0.01 M solution from given 0.1 M solution of potassium permanganate.

Given Data

$M_1 = 0.1\,M$

$V_2 = 100\ cm^3$

$M_2 = 0.01\ M$

Required Data:

$V_1 = ?$

Solution:

i. Determination of volume of concentrated solution:

First 0.1 M solution is prepared by dissolving 15.8 g of potassium permanganate in 1 dm^3 of solution. Then 0.01 M solution is prepared by the dilution according to following calculations:

Preparation of 0.01M, 100cm^3 $KnmO_4$ solution =?

$$V_1 = ?$$

Putting the values in equation we get:

Concentrated solutions = dilute solution:

$$V_1 \times 0.1 = 0.01 \times 100$$

$$V_1 \times 0.1 = 0.01 \times 100$$

$$V1 = 0.01 \times 100 = 10cm^3$$

Concentrated solution of $KMnO_4$ has dense purple colour.

ii. Preparation of Solution:

We take 10 cm^3 of this solution with the help of a graduated pipette and put in a measuring flask of 100 cm^3. Add water upto the mark present at the neck of the flask. Now it is 0.01 molar solution of $KMnO_4$.

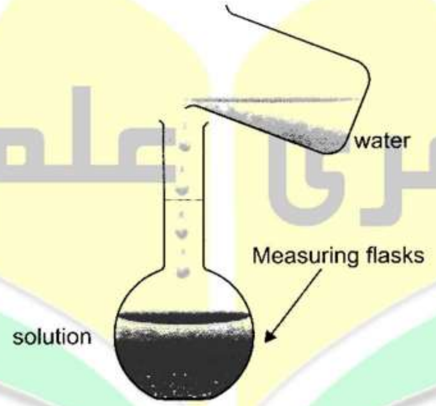


Fig. 6.1 Dilution of a solution.

Q:8 What is solubility? Write down the factors affecting solubility.

Or

What is general principle of solubility? (Ex. Q.6)

Explain solute – solvent interactions in the preparation of a solution. (Ex.Q.5)

Discuss the effect of temperature on solubility. (Ex.Q.7)

Ans: Solubility

The number of grams of the solute dissolved in 100 g of solvent to prepare a saturated solution at a particular temperature.

The concentration of a saturated solution is referred to as solubility of the solute in a given solvent.

Factor affecting the solubility

Following are the factors which affect the solubility of solutes:

a. Nature of solute and solvent (like dissolves like)

b. Solute-solvent interactions

c. Temperature

a. Like dissolves like (Nature of solute and solvent):

The general principle of solubility is, like dissolves like.

i. The polar substances are soluble in polar solvents. Ionic solids and polar covalent compounds are soluble in water

Examples: KCI, Na_2CO_3, $CuSO_4$, sugar and alcohol are soluble in water

ii. Non-polar substances are not soluble in polar solvents.

Examples: Ether, benzene and petrol are all in soluble in water

iii. Non-polar covalent substances are soluble in non-polar solvents (mostly organic solvents).

Examples: Grease, paints, naphthalene are soluble in ether or carbon tetrachloride etc.

b. Solubility and Solute-solvent interactions:

The solute-solvent interaction can be explained in terms of creation of attractive forces between the particles of solute and those of solvent.

Steps to dissolve solute in solvent:

To dissolve one substance (solute) in another substance (solvent) following three events must occur:

i. Solute particles must separate from each other

ii. Solvent particles must separate to provide space for solute particles.

iii. Solute and solvent particles must attract and mix up.

Dependence of solution formation:

Solution formation depends upon the relative strength of attractive forces between solute- solute, solvent-solvent and solute-solvent.

Physical states of solute and nature of interactions:

i. Generally solutes are solids. Ionic solids are arranged in such a regular pattern that the inter-ionic forces are at a maximum.

ii. If the new forces between solute and solvent particles overcome the solute-solute attractive forces, then solute dissolves and makes a solution.

iii. If forces between solute particles are strong enough than solute-solvent forces, solute remains insoluble and solution is not formed.

iv. The solvent molecules first pull apart the solute ions and then surround them. In this way solute dissolves and solution forms.

Example: (Dissolution of sodium chloride)

When NaCl is added in water it dissolves readily because the attractive interaction between the ions of NaCl and polar molecules of water are strong enough to overcome the attractive forces between Na^+ and Cl^- ions in solid NaCl crystal. In this process the positive end of the water dipole is oriented towards the Cl^- ions and the negative end of water dipole is oriented towards the Na^+ ions. These ion-dipole attractions between Na^+ ions and water molecules, Cl^- ions and water molecules are so strong that they pull these ions from their positions in the crystal and thus NaCl dissolves.

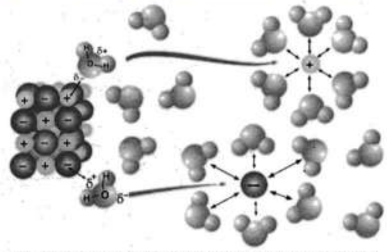


Fig. 6.2 Inter-action of solute and solvent to form solution.

Q:9 Discuss the effect of temperature on solubility?

Ans: Effect of Temperature on solubility:

Temperature has major effect on the solubility of most of the substances. Generally it seems that solubility increases with the increase of temperature, but it is not always true. When a solution is formed by adding a salt in solvent there are three possibilities with reference to effect of temperature on solubility.

These possibilities are discussed here.

i. Heat is absorbed

ii. Heat is given out.
iii. No change in heat

Heat is absorbed (Endothermic Process)

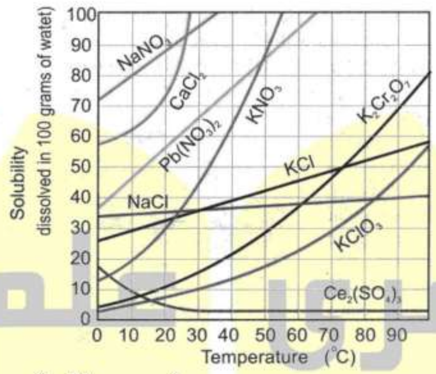
Solubility usually increases with the increase in temperature for such solutes. When salts like KNO_3, $NaNO_3$ and KCl are added in water, the test tube becomes cold. It means during dissolution of these salts heat is absorbed. Such dissolving process is called "endothermic".

$$\text{solvent} + \text{solute} + \text{heat} \longrightarrow \text{solution}$$

Reason:

It means that heat is required to break the attractive forces between the ions of solute. This requirement is fulfilled by the surrounding molecules. As a result, their temperature falls down and test tube becomes cold.

Examples: KNO_3, $NaNO_3$, KCl, NH_4Cl, $CaCl_2$, $CuSO_4$ etc.



ii. Heat is given out (Exothermic Process).

Reason:

In such cases, the solubility of salt decreases with the increase of temperature
When salts like Li_2SO_4 and $Ce_2(SO_4)_3$ are dissolved in water, the test tube becomes warm. i.e. heat is released during this dissolution.

$$\text{solvent} + \text{solute} \longrightarrow \text{solution} + \text{heat}$$

In such cases attractive forces' among the solute particles are weaker and solute- solvent interactions are stronger. As a result, there is release of energy.

Examples: Li_2CO_3, $Ca(OH)_2$, Li_2SO_4,$CaCrO_4$ etc.

iii. No change in heat:

In some cases during a dissolution process neither the heat is absorbed nor released. When salt like NaCI is added in water, the solution temperature remains almost the same. In such case temperature has a minimum effect on solubility.

6.6 comparison of solution, suspension and colloid

Q:10 Explain the solution, suspension and colloid.

OR

a. Give the five characteristics of true solution.
b. (Ex.Q.8): Give the five characteristics of colloid.
c. (Ex.Q.9): Give at least five characteristics of suspension.

Ans: a. True Solution:

"A homogeneous mixture of two or more than two components is called true solution."

Examples: Solution of NaCl in water, drop of ink mixed in water (simplest example of true solution) and solution of sugar in water

Properties:

i. The particles exist in their simplest form i.e. as molecules or ions. Their diameter is 10^{-8}cm.

ii. Particles dissolve uniformly throughout and form a homogeneous mixture.

iii. Particles are so small that they can't be seen with naked eye.
iv. Solute particles can pass easily through a filter paper.
v. Particles are so small that they cannot scatter the rays of light, thus do not show Tyndall effect.

b. Colloid / False solution / Colloidal Solution:

"These are solutions in which the solute particles are larger than those present in the true solutions but not large enough to be seen by naked eye."

Tyndall Effect:

"The particles of colloids are big enough to scatter the beam of light. It is called Tyndall effect."

Tyndall effect and distinction between colloid and solution:

We can see the path of scattered light beam inside the colloidal solution. Tyndall effect is the main characteristic which distinguishes colloids from solutions. Hence these solutions are called false solutions or colloidal solutions.

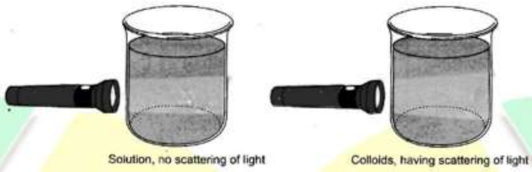


Fig. 6.4 Tyndall effect by colloids.

Examples: Starch, Albumin, Soap solutions, Blood, Milk, Ink, Jelly, Toothpaste etc

Properties:
i. The particles are large consisting of many atoms, ions or molecules.
ii. A colloid appears to be a homogeneous but actually it is a heterogeneous mixture. Hence, they are not true solution. Particles do not settle down for a long time, therefore, colloids are quite stable.
iii. Particles are large but can't be seen with naked eye.
iv. Although particles are big but they can pass through a filter paper.
v. Particles scatter the path of light rays thus emitting the beam of light i.e. exhibit the tyndall effect.

6.6.3 Suspension

"A heterogeneous mixture of undisclosed particles in a given medium that settles down after some time is called suspension."

Examples: Chalk in water (milky suspension), Paints and milk of magnesia (suspension of magnesium oxide in water)

Properties:
i. The particles are of largest size. They are larger than 10^{-5}cm in diameter.
ii. Particles remain un-dissolved and form a heterogeneous mixture. Particles settle down after sometime
iii. Particles are big enough to be seen with naked eye.
iv. Solute particles cannot pass through filter paper.
v. Particles are so big that light is blocked and difficult to pass.

Q:11 How you can compare solutions, colloid and suspension?

Ans: Comparison of the characteristics of solution, colloid and suspension

Solution	Colloid	Suspension
i. Size of particles: The particles exist in their simplest form i.e. as molecules or ions. Their diameter is 10^{-8} cm.	**i.** The particles are large consisting of many atoms, ions or molecules.	**i.** The particles are of largest size. They are larger than 10^{-5}cm in diameter.

ii. Solubility of particles: Particles dissolve uniformly throughout and form a homogeneous mixture.	**ii.** A colloid appears to be a homogeneous but actually it is a heterogeneous mixture. Hence, they are not true solution. Particles do not settle down for a long time, therefore, colloids are quite stable.	**ii.** Particles remain un-dissolved and Form a heterogeneous mixture. Particles settle down after sometime
iii. Observation with naked eye: Particles are so small that they can't be seen with naked eye.	**iii.** Particles are large but can't be seen with naked eye.	**iii.** Particles are big enough to be seen with naked eye.
iv. Passing through filter paper: Solute particles can pass easily through a filter paper.	**iv.** Although particles are big but they can pass through a filter paper.	**iv.** Solute particles cannot pass through filter paper.
v. Tyndall effect: Particles are so small that they cannot scatter the rays of light, thus do not show Tyndall effect.	**v.** Particles scatter the path of light rays thus emitting the beam of light i.e. exhibit the tyndall effect.	**v.** Particles are so big that light is blocked and difficult to pass.