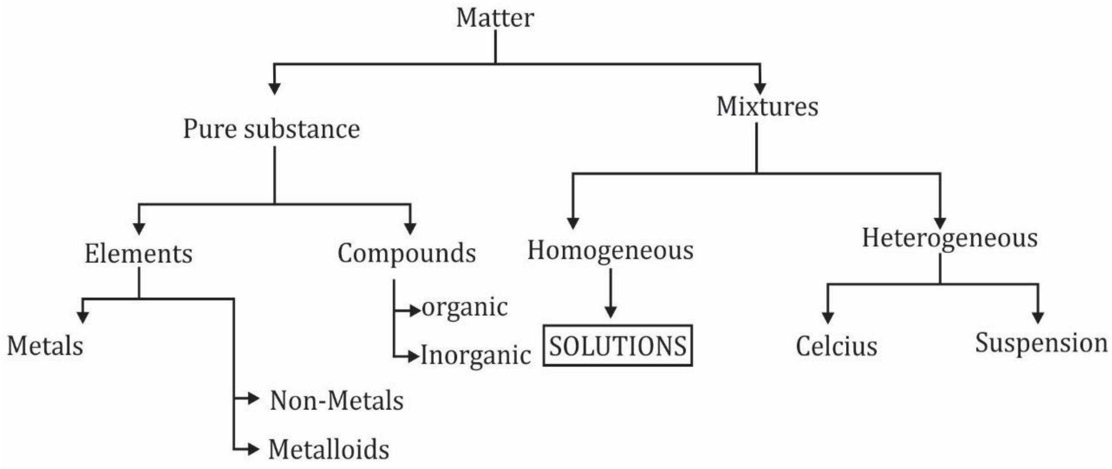
SOLUTION

CHAPTER – 2

SOLUTION



What is Solution?

A homogeneous mixture of two or more substances in related amounts can vary continuously up to the so-called melting point. The term solution is often used in the liquid state of objects, but gas and solid solutions are possible. On the basis of the number of components the two-part solution is called a binary solution.

Solute:

The substance that dissolve in the solvent to produces a homogeneous mixture.

An excellent example of a solute in our daily work is salt and water. Salt dissolves in water so, salt is a solute.

Solvent:

The term 'solvent' can be defined as something that has a dissolving solvent that is given to form a solution.

Typical examples of smelting include water, ethanol, methanol and acetone.

Separation of solutions

The solution can be classified as a solid, liquid and gaseous solution.

(A) The following types of solutions are based on the solute and solvent composition:

Type of solution	Solute	Solvent	Examples
Gaseous solution	Gas	Gas	Mixture of H_2 and O_2 gas.
	Liquid	Gas	Air containing moisture
	Solid	Gas	Homogeneous mixture of camphor in N_2 gas
Liquid solution	Gas	Liquid	Homogeneous mixture of CO_2 gas in water
	Liquid	Liquid	Homogeneous mixture of water and ethanol
	Solid	Liquid	Homogeneous mixture of sugar and water
Solid solution	Gas	Solid	Adsorption of H_2 gas in Pd.
	Liquid	Solid	Zinc amalgam Zinc dissolved in mercury (Zn/Hg)
	Solid	Solid	Alloy formed from copper and zinc (Brass)

(B) Depending on the amount of solute dissolved in the solvent we have the following types of solution:

Saturated Solution:

A saturated solution is a solution where a high amount of solute is dissolved under current conditions.

A complete solution containing a high solute value that can be dissolved in a given solvent value at a certain temperature is called a complete solution.

Unsaturated Solution:

An unsaturated solution is a solution that contains less than the maximum solute value of the solute. If more solute was added and did not dissolve, then the first solution was full. If the excess solute melted, then the first solution was unsaturated.

Supersaturated Solution:

A supersaturated solution is usually soluble even in solid form once cooled. An example of a supersaturated solution is sodium acetate in water. Sodium acetate salt acetic acid or vinegar. Water is a common solvent for supersaturated solvents because they can be safely heated.

Solubility:

Solubility is the ability of a solid, liquid, or gaseous chemical (referred to as a solute) to dissolve in a solvent (usually a liquid) and form a solution. The solubility of a substance in a certain solvent is measured by the combination of a complete solution.

Factors affecting solubility

- Temperature. Basically, the melting increases with the temperature.
- Polarity. In most cases the solvents are soluble in solvents with the same polarity.
- Pressure. Solid and liquid solutions.
- Cell size.
- Motivation increases the speed of completion.

Solubility of solute in liquids depends on the following factors:

- Solute environment
- Type of solvent
- The temperature of the solution
- Gas pressure

Factors affecting solubility of a solid in a liquid :

Nature of solute and solvent: Polar solutes dissolve in polar solvents and non-polar solutes in non-polar solvents. (i.e., like dissolves like).

Effect of temperature:

- If the dissolution process is endothermic ($\Delta_{sol} H > 0$), the solubility increases with rise in temperature.
- If dissolution process is exothermic ($\Delta_{sol} H < 0$), the solubility decreases with rise in temperature.

Effect of pressure: Pressure does not have any significant effect on solubility of solids in liquids as these are highly incompressible.

Factors affecting solubility of a gas in a liquid :

Effect of pressure: Henry's law states that "the partial pressure of the gas in vapour phase (p) is proportional to the mole fraction of the gas (x) in the solution"

p = KH x where, KH is the Henry's law constant and is different for different gases at a particular temperature.

Higher the value of KH at a given pressure, the lower is the solubility of the gas in the liquid.

Effect of temperature: As dissolution is an exothermic process, then according to Le Chatelier's principle, the solubility should decrease with increase of temperature.

Henry's Law:

Legally at a constant temperature, the melting of a gas in a liquid is directly related to the pressure of the gas. It can also be said - The pressure of a gas fraction in the vapor phase (p) is proportional to the gas molecule (x) in solution.
It can be expressed by
p = KH. x
The greater the amount of KH, the higher the melting. The amount of KH decreases with increasing temperature.

Application of Henry's law:

- Sealing of soft drink bottles in high pressure increases the melting of CO2 in soft drinks and soda water.
- When a diver dives into the water, his body is under a lot of pressure. As a result, body tissues absorb more gases. Oxygen breathing is needed for cellular respiration to give energy to the diver. But nitrogen enters the body's tissues.
- At higher altitudes half the oxygen weight is not the same as at low altitudes. This promotes low oxygen levels in the blood and tissues of people who live in high places or climb mountains. Decreased blood pressure causes mountain climbers to feel weak and unable to think clearly, indications of a condition known as anoxia.

Concentration of solution:

The concentration of the solution is a measure of the amount of solute dissolved in a given amount of solvent or solution.

A concentrated solution is one that contains a very high amount of soluble solute.

A dilute solution is one that has a very small amount of solute solute.

Ways to express the concentration of the solution

(1) Mass / Weight Percentage or Percentage of Mass / Weight

Mass percentage can be defined as the ratio of Mass of the component of the solution and total mass of the solution multiplied by 100%.

$$Mass\ Percentage = \frac{Mass\ of\ Solute}{Mass\ of\ Solution} \times 100$$

$$= \frac{Mass\ of\ Solute}{Mass\ of\ Solute + Mass\ of\ Solvent} \times 100$$

$$= \frac{Mass\ of\ Solute}{Volume\ of\ Solution + Density\ of\ Solution} \times 100$$

The solute and solvent ratio is a large fraction. Therefore, a large percentage of solute = Half Mass × 100. A 10% sugar solution in bulk means that 10 grams of sugar is present in 100 grams of solution, that is, we dissolve 10 grams of sugar in 90 grams water.

(2) Volume Percentage

Volume percentage can be defined as the ratio of Volume of the component of the solution and total mass of the solution multiplied by 100%. The formula will be:

$$Volume\ Percentage = \frac{Volume\ of\ Solute}{Volume\ of\ Solution} \times 100$$

A 10% solution of HCl by volume means that 10 mL of liquid HCl is present in 100 mL of solution.

(3) Mass by Volume Percentage

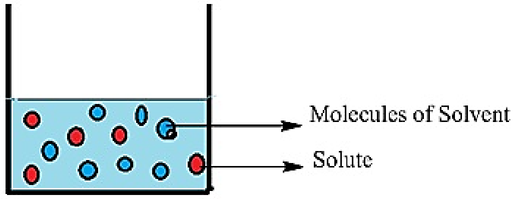
Mass by volume percentage can be defined as the mass of solute dissolved in 100 mL of the solution.
For instance, mass by volume percent of a solution with 1 g of solute dissolved in 100 mL of solution will be 1% or 1% (mass/volume). The formula will be:

$$\text{Mass by Volume Percentage} = \frac{Mass\ of\ Solute}{Volume\ of\ Solution} \times 100$$

A volume solution of 10% per volume means that 10 gm solute is present in 100 mL of solution.

(4) Molarity

Molarity (M) can be defined as the ratio of number of moles of solute to the volume of solution in liter.



It can also be defined as the number of moles of solute present in unit litre or cubic decimeter of solution.
It is function of temperature due to the dependence of volume on temperature whereas Mass %, ppm, mole fraction and molality are independent of temperature because mass does not depend on temperature.

$$Molarity(M) = \frac{Number\ of\ moles\ of\ solute}{Volume\ of\ Solution\ in\ L}$$

For example, a mol L-1 solution for KCl means that 1 mol of KCl dissolves in 1 L of water. Molarity unit: mol L-1

(5) Molality

Molality (m) can be defined as the ratio of number of moles of solute to the mass of solvent in kg.
It can also be defined as the number of moles of solute present in unit kilogram of solvent.

$$Molality\ (m) = \frac{Number\ of\ moles\ of\ solute}{Mass\ of\ Solvent\ in\ kg}$$

Therefore, if a molecule of one gram of solute is present in 1 kg of solvent, the concentration of the solution is called one molal. The unit of molarity is mol kg-1. Molality is a very simple way to express a mixture of solutions because it absorbs more liquid than its volume. It is also independent of temperature variations.

(6) Normality

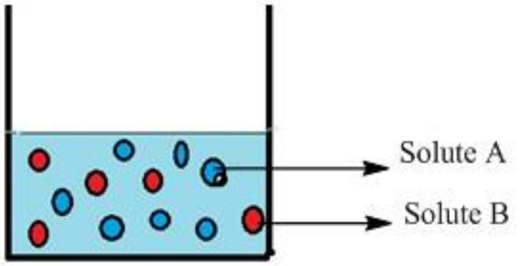
The no. of equivalents of solute present in one litre of a solution is called the Normality (N)

$$\text{Normality} = \frac{\textit{Number of gram equivalents of solute}}{\textit{Volume of Solution in L}}$$

Therefore, if a gram equivalent to a solute is present in one liter of solution, the concentration of the solution is said to be 1 normal.

(7) The Mole fraction

Mole fraction can be defined as the ratio of number of moles of the component in the solution to the total number of moles of all components in the solution.



It is denoted by the alphabet x and subscript written on the right hand side of x denotes the component of which mole fraction is being calculated. For solution A and B

Mole Fraction of A (XA) = $\frac{n_A}{n_A + n_B}$

Mole Fraction of B (XB) = $\frac{n_B}{n_A + n_B}$

And, XA+XB = 1

(8) Parts per million (ppm)

Parts per million can be defined as the ratio of number of parts of the component to the total number of parts of all components of the solution multiplied by 106.

It is denoted by ppm.

It is used to express concentration of a solution where solute is present in trace For instance, concentration of pollutants in water or atmosphere is expressed in terms of g mL-1 or ppm. The formula is as follows:

$$\text{Ppm} = \frac{\textit{Number of parts of the component}}{\textit{Total number of parts of the compoenents in the solution}} \times 10^6$$

In the case of weight, we may present it as follows: (Solute weight / Solution weight) × 10^6

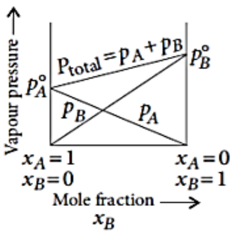
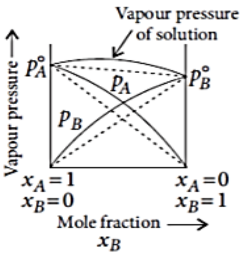
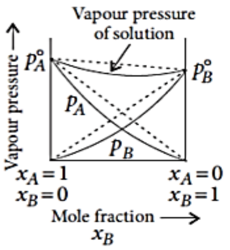
In the case of volume, we can present it as: (Solute volume / Solution volume) × 10^6

Therefore, we can express the concentration of solutions in parts of each million such as weight depending on size, volume to volume and weight in volume form. Air pollution in cities is also expressed at ppm by volume. Refer to the volume of impurities per 10^6 units of volume. 10 ppm of SO_2 in the air means that 10 mL of SO_2 is present in 10^6 mL of air

Raoult's law:

Raoult's law establishes a quantitative relationship between the partial vapour pressure and mole fraction of a solution. This law is only for liquid-liquid solution.

The law states that for a solution of volatile liquids, the partial vapour pressure (p) of each component in the solution is directly proportional to its mole fraction (x).

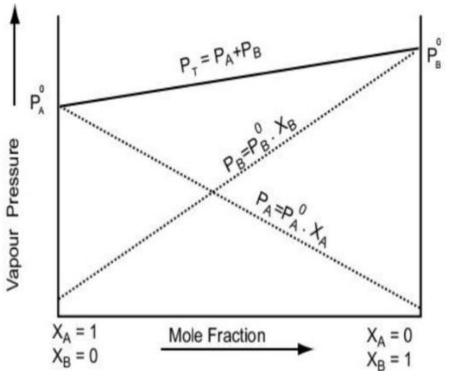
Ideal solutions	**Non-ideal solutions**	
	Positive deviation from Raoult's law	**Negative deviation from Raoult's law**
		
$A-B$ interactions ≈ $A-A$ and $B-B$ interactions	$A-B$ interactions << $A-A$ and $B-B$ interactions	$A-B$ interactions >> $A-A$ and $B-B$ interactions
$\Delta H_{mix} = 0, \Delta V_{mix} = 0$	$\Delta H_{mix} > 0, \Delta V_{mix} > 0$	$\Delta H_{mix} < 0, \Delta V_{mix} < 0$
e.g., dilute solution, benzene + toluene, *n*-hexane + *n*-heptane	*e.g.*, acetone + ethanol, acetone + CS_2, water + methanol	*e.g.*, acetone + aniline, acetone + chloroform, $CH_3OH + CH_3COOH$

For a solution that contains both fluids A and B, the component pressure of fluid A is

$$p_A \propto \chi_A \quad \text{or} \quad p_A = k\chi_A$$

where, $\chi_A = \dfrac{n_A}{(n_A + n_B)}$ = mole fraction of liquid A

Proportionality constant is obtained by considering a pure liquid where XA = 1 and k = P0A, the pressure of pure liquid vapour is,



Similarly, $P_A = P\mathring{A}\chi_A$

$$p_B = p_B^{\circ}\chi_B$$

The total vapour pressure of the solution

$$p_T = p_A + p_B = p_A^{\circ}\,\chi_A + p_B^{\circ}\,\chi_B$$

$$= p_A^{\circ} + (p_B^{\circ} - p_A^{\circ})\chi_B$$

Raoult's law applies as follows:

- Measure the reduction of vapour pressure in a constant solute.
- Measuring the mixing capacity of liquids.

Note: A solution that complies with Raoult's rule is known as the correct solution (no volume change in mixing and no change in enthalpy).

Dalton's law of partial pressures :

$$P_{\text{total}} = p_1 + p_2 = x_1 p_1^{\circ} + x_2 p_2^{\circ}$$

$$= (1 - x_2)p_1^{\circ} + x_2 p_2^{\circ}$$

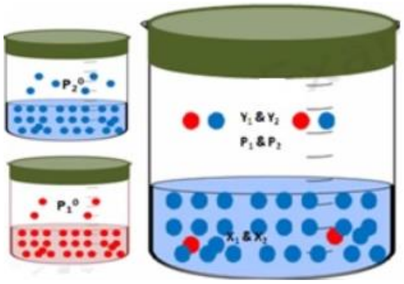
$$= p_1^{\circ} + (p_2^{\circ} - p_1^{\circ})x_2$$

If y_1 and y_2 are the mole fractions of the components 1 and 2 respectively in the vapour phase then, $p_1 = y_1 P_{\text{total}}$ and $p_2 = y_2 P_{\text{total}}$

Raoult's law for solid-liquid solutions: It states that relative lowering in vapour pressure of a solution containing a non-volatile solute is equal to the mole fraction of the solute.

$$\frac{p^{\circ} - p_s}{p^{\circ}} = x_2 \text{ where,}$$

p° = vapour pressure of pure solvent
p_s = vapour pressure of solution
x_2 = mole fraction of solute.



According to the Raoult Law, liquid-liquid solutions can be of two types. They are:

Ideal solution:

Solutions that comply with Raoult's Law on the whole range of concentration and at all temperatures are Ideal Solutions.

Raoult's law as special case of Henry's law

At a given temperature liquids vaporize. At equilibrium the pressure exerted by the vapour of the liquid over the liquid phase is referred to as vapour pressure.

According to Raoult's law, vapour pressure of a volatile component in a given solution can be defined by $p_i = p_i^0 x_i$

In an answer of a gas in a fluid one of the segments is volatile to the point that it exists as a gas and solvency is given by Henry's law which expresses that $p = K_H x$

Comparing both the equations we get that partial pressure of the volatile component or gas is directly proportional to its mole fraction in solution. Proportionality constant K_H differs from p10

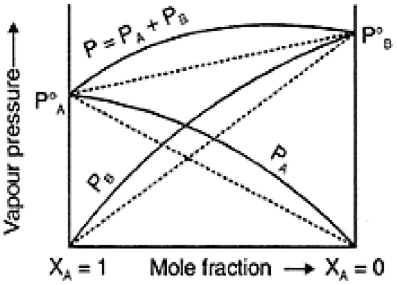
Therefore, Raoult's law turns into a unique instance of Henry’s law in which K_H get to be equivalent to p_{10}.

Features of Ideal Solutions

- They follow Raoult's Law. This means that the component pressure of components A and B in the solution will be $P_A = P_A^0 x_A$ and $P_B = P_B^0 x_B$. P_A^0 and P_B^0 evaporate pressure in a clean manner. On the other hand, x_A and x_B are the molecular components of components A and B
- The enthalpy mixing of two parts should be zero, i.e., $\Delta_{mix} H = 0$. This means that no heat escapes or is absorbed during the mixing of two clean parts to form a suitable solution.
- The mixing volume is equal to zero i.e., $\Delta_{mix} V = 0$. This means that the total volume of the solution is exactly the same as the total volume of solute and solution. Adding further, it also means that there will be a reduction or volume increase while the integration of the two components takes place.
- Solute-solute interactions and solvent-solvent interactions are almost identical to solute-solvent interactions.

Non-ideal solution:

Remedies that do not comply with Raoult's law on the whole focus list and at all temperatures are Bad Solutions.



P-X graph for non-ideal solution showing +ve deviation

Features of Non-ideal Solutions

- Solute-solute and solvent-solvent interactions differ from those of solute-solvent interactions
- Mixing enthalpy i.e., $\Delta_{mix} H \neq 0$, meaning heat can be released if the mixing enthalpy is negative ($\Delta_{mix} H < 0$) or heat may be detected if the mixing enthalpy is correct ($\Delta_{mix} H > 0$)
- The volume of the mixing, $\Delta_{mix} V \neq 0$, indicates that there will be some expansion or contraction of the liquid.

Non-ideal solutions are of two types:

Non-ideal solutions that demonstrate a positive deviation from Raoult's Law

Non-ideal solutions that reflect a negative deviation from the Raoult Act

Azeotropes: The mixtures of liquids which boil at constant temperature like a pure liquid and possess same composition of components in liquid as well as vapour phase are called constant boiling mixtures or azeotropic mixtures.

Minimum boiling azeotropes: They formed by those liquid pairs which show positive deviations from ideal behaviour e.g., ethanol-water mixture.

Maximum boiling azeotropes: They are formed by those liquid pairs which show negative deviations from ideal behaviour e.g., nitric acid-water mixture.

Colligative properties:

The colligative properties of solutions are factors that depend on the fusion of solute or ion molecules, but not on solute ownership. Compounding factors include lower evaporation pressure, elevated boiling point, cold point stress, and osmotic pressure.

Relative lowering of vapour pressure: When a nonvolatile solute is dissolved in a solvent, vapour pressure of the solution is lower than that of the pure solvent which is known as lowering of vapour pressure. Relative lowering of vapour pressure is equal to the mole fraction of the solute in the solution.

$$\frac{p_A^\circ - p_A}{p_A^\circ} = \chi_B$$

where, $\frac{p_A^\circ - p_A}{p_A^\circ}$ = relative lowering of vapour pressure

$$\frac{p_A^\circ - p_A}{p_A^\circ} = \frac{n_B}{n_A + n_B}$$

for dilute solutions, $n_B << n_A$. Hence,

$$\frac{p_A^\circ - p_A}{p_A^\circ} = \frac{n_B}{n_A}$$

OR

$$\frac{p_A^\circ - p_A}{p_A^\circ} = \frac{W_B \times M_A}{M_B \times W_A}$$

$$M_B = \frac{W_B}{W_A} \times M_A \times \frac{p_A}{(p_A^\circ - p_A)}$$

The above term is used to determine the weight of an unknown solute molecule dissolved in a solvent. There, W_B and W_A are mass solute and solvent respectively. M_B and M_A of solute and solvent molecular weight respectively.

Boiling point elevation:

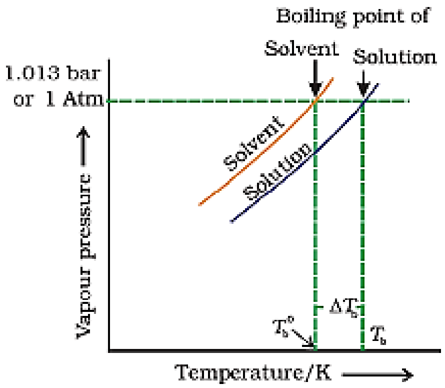
The higher the boiling point refers to the fact that the boiling point of the liquid (solvent) will be higher when another compound is added, meaning that the solution has a higher boiling point than pure solvent. This occurs whenever a solid solute, like salt, is added to a pure solvent, such as water.

$$\Delta T_b = \frac{K_b \cdot W_B \times 1000}{M_B \times W_A}$$

$$M_B = K_b \cdot \frac{W_B}{W_A} \times \frac{1000}{\Delta T_b}$$

There, W_B and W_A = solute and solvent weight respectively.

K_b has units of K / m or K kg mol^{-1}, of water, K_b = 0.52 K kg mol^{-1}



Depression in freezing point:

Freezing point depression is an event that explains why adding a solute to a solvent leads to a reduction in the freezing point of the solvent. When an object begins to freeze, molecules slow down due to a decrease in temperature, and intermolecular forces begin to take over.

Depression in freezing point $(\Delta T_f) = T_f^o - T_f$

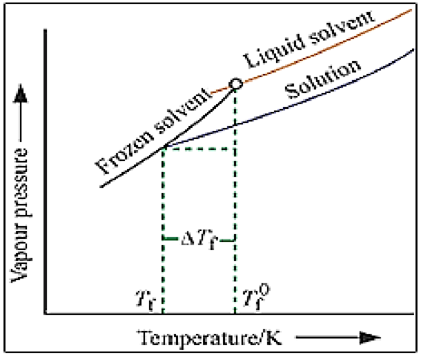
$$\Delta T_f = K_f . m = K_f \frac{W_B}{M_B} \times \frac{1000}{W_A}$$

To find molecular mass of solute,

$$M_B = \frac{K_f . W_B \times 1000}{\Delta T_f . W_A}$$

Where, K_f is molal depression constant or cryoscopic constant.

K_f has units of K/m or K kg mol^{-1}



Osmotic Pressure:

Osmosis is defined as the flow of a net or the movement of solvent atoms through a semipermeable membrane through which solute molecules cannot pass through. When a solution consisting of both solute and solvent molecules is placed on one side of the membrane and a pure solvent is placed on the other side, there is a net flow of solvent on the side of the membrane solution.

$$\text{Osmotic pressure } (\pi) = RCT; \left(C = \frac{n_B}{V} = \frac{W_B}{M_B V}\right)$$

$$M_B = \frac{W_B RT}{\pi V}$$

$$\pi = \frac{dRT}{M_B} ; \left(d = \frac{W_B}{V}\right)$$

There, d = density, R = constant solution, T = temperature, MB = molar solute weight.

Based on osmotic pressure, the solution could be:

1. Hypertonic Solution:

A solution that contains more soluble particles (such as salts and other electrolytes) than those found in normal cells and blood. For example, hypertonic solutions are used to soothe wounds.

2. Hypotonic Solution:

Hypotonic solutions have a lower concentration of soluble solutes than blood. An example of a hypotonic IV solution is 0.45% Normal Salt (0.45% NaCl). When hypotonic IV solutions are introduced, it leads to a reduction in the concentration of soluble substances in the blood compared to the intracellular space.

3. Isotonic Solutions:

Two solutions with the same osmotic pressure across the semipermeable membrane are called isotonic solutions. It has the same solute concentration, as another solution. Other examples of isotonic solutions are 0.9% common saline and lactated rings.

With isotonic solutions, $\pi_1 = \pi_2$ Also, $C_1 = C_2$

Reverse Osmosis:

Reverse Osmosis (RO) is a water purification process that uses a slightly more flexible membrane to separate ions, unwanted molecules, and larger particles from drinking water. The result is that the solute is kept on the pressed side of the membrane and the pure solvent is allowed to pass through the other side.

Van't Hoff Factor:

The van 't Hoff factor is a measure of the effect of solute in which there are conflicting factors such as osmotic pressure, moderate decrease in vapour pressure, elevated boiling point and freezing point stress.

The van 't Hoff factor is the ratio between the actual interaction of particles produced when an object is dissolved and the interaction of an object as calculated from its mass.

$$i = \frac{\text{Normal molar mass}}{\text{Observed molar mass}}$$

$$\text{or } \quad i = \frac{\text{Calculated molar mass}}{\text{Experimental molar mass}}$$

Concentration rate and van't hoff factor:

If the atoms of the A element are connected to form A and A is a junction, then

	nA	$\rightarrow$	A_n
Totally	1 mol		0
At equilibrium	$1-\alpha$		$\frac{\alpha}{n}$

Total number of moles at equilibrium

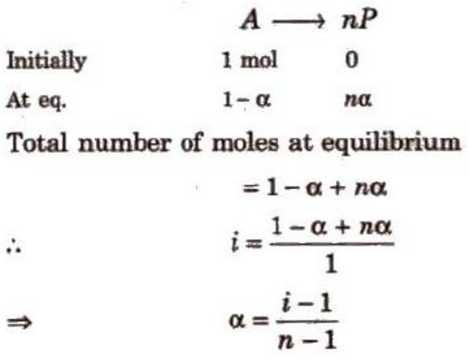
$$= 1 - \alpha + \frac{\alpha}{n}$$

$$i = \frac{1-\alpha+\frac{\alpha}{n}}{1}$$

$$\Rightarrow \quad \alpha = \frac{i-1}{\frac{1}{n}-1}$$

Degree of dissociation and van't hoff factor:

The one molecule of an object is divided into n particles and a is a fraction



$$A \longrightarrow nP$$

	A	nP
Initially	1 mol	0
At eq.	$1-\alpha$	$n\alpha$

Total number of moles at equilibrium

$$= 1 - \alpha + n\alpha$$

$$\therefore \quad i = \frac{1-\alpha+n\alpha}{1}$$

$$\Rightarrow \quad \alpha = \frac{i-1}{n-1}$$

Degree of Association (α) and van't Hoff Factor (i)

Van't hoff factor (i)> 1 of soluble solvents and is < 1 of soluble solvents.

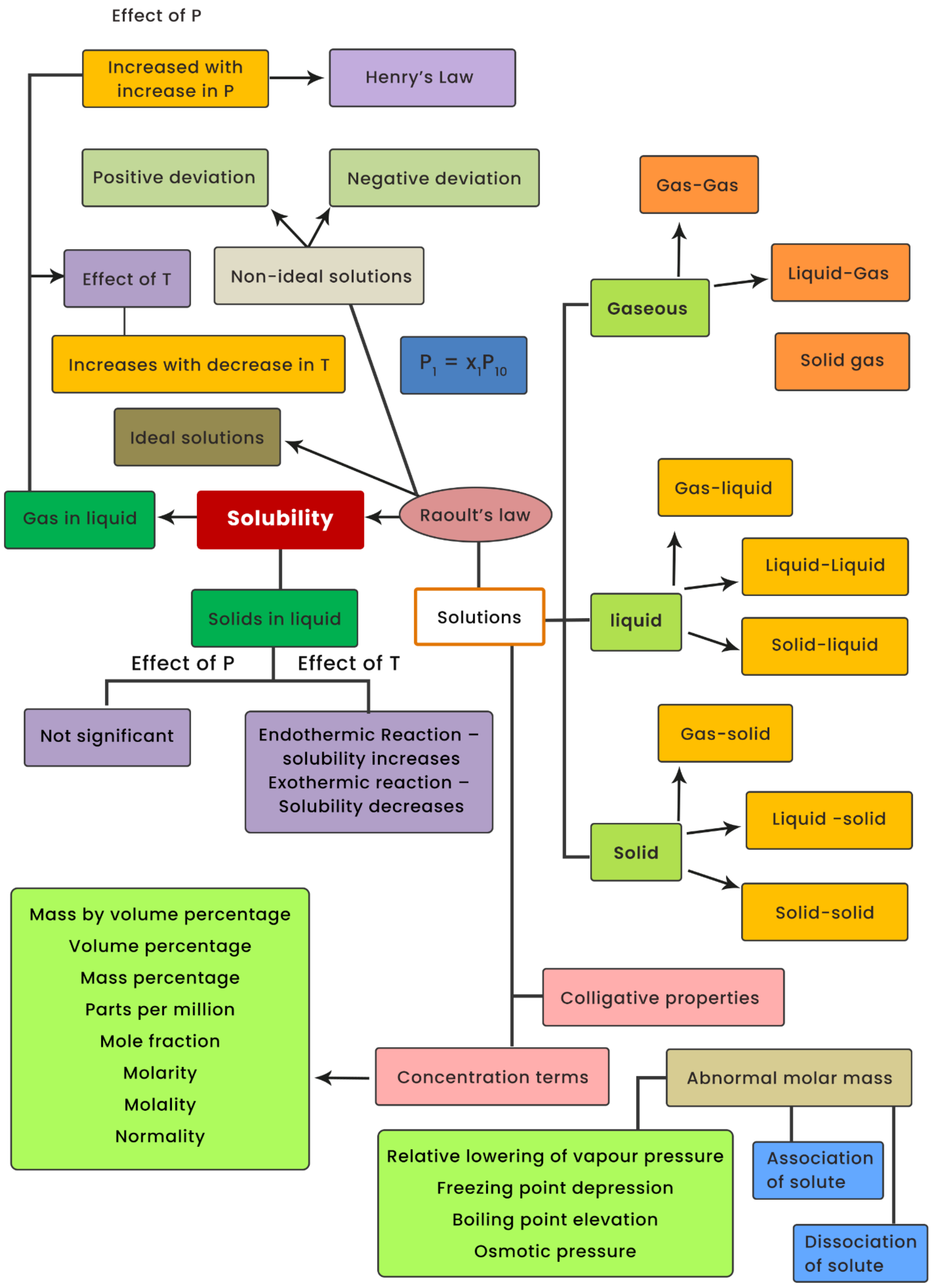
SUMMARY

A solution is a homogeneous mixture of two or more substances. Solutions are calssidied as solid, liquid and gaseous solutions. The concentration of a solution is expressed in terms of mile fraction, molarity, molality and in percentages. The dissolution of a gas in a liquid is governed by Henry's law, according to which, at a given temperature, the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas. The vapour pressure of the solvent is lowered by the pressure of non-volatile solute in the solution and this lowering of vapour pressure of the solvent is governed by Raoult's law, according to which the relative lowering of vapour oreyof the solvent over a solution is equal to the mile fraction of a non-volatile solute present in the solution. However, in a binary liquid solution, if both the components of the solution are volatile then another form of Raoult's law is used. Mathematically this form of the Raoult's law is stated as: ptotal = $P_1^{0\times1}+ P_2^{0\times2}$. Solutions which obey Raoult's law over the entire range of concentration are called ideal solutions. Two types of deviations from Raoult's law, called positive and negative deviations are observed. Azeotropes arise due to very large deviations from Raoult's law.

The properties of solutions which depend on the number of solute particles are independent of their chemical identity are called colligative properties. These are lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure. The process of osmosis can be reversed if a pressure higher than the osmotic pressure is applied to the solution. Colligative properties have been used to determine the molar mass of solutes. Solutes which dissociate in solution exhibit molar mass lower than the actual molar mass and those which associate show higher molar mass than their actual values.

Quantitatively, the extent to which a solute is dissociated or associated can be expressed by can't Hoff factor i. This factor has been defined as ratio of normal molar mass to experimentally determined molar mass or as the ratio of observed colligative property to the calculated colligative property.

MIND MAP



Effect of P

Increased with increase in P

Henry's Law

Positive deviation

Negative deviation

Gas-Gas

Effect of T

Non-ideal solutions

Gaseous

Liquid-Gas

Increases with decrease in T

$P_1 = x_1P_{10}$

Solid gas

Ideal solutions

Gas-liquid

Gas in liquid

Solubility

Raoult's law

Liquid-Liquid

Solids in liquid

Solutions

liquid

Solid-liquid

Effect of P

Effect of T

Not significant

Endothermic Reaction – solubility increases
Exothermic reaction – Solubility decreases

Gas-solid

Liquid -solid

Solid

Solid-solid

Mass by volume percentage
Volume percentage
Mass percentage
Parts per million
Mole fraction
Molarity
Molality
Normality

Colligative properties

Concentration terms

Abnormal molar mass

Relative lowering of vapour pressure
Freezing point depression
Boiling point elevation
Osmotic pressure

Association of solute

Dissociation of solute

MULTIPLE CHOICE QUESTIONS

1. Out of molality (m), molarity (M), formality (F) and mole fraction (x), those which are independent of temperature are
(a) M, m
(b) F, x
(c) m, x
(d) M, x

2. The boiling point of an azeotropic mixture of water and ethanol is less than that of water and ethanol. The mixture shows
(a) No deviation from Raoult's Law.
(b) Positive deviation from Raoult's Law.
(c) Negative deviation from Raoult's Law.
(d) That the solution is unsaturated.

3. Which has the lowest boiling point at 1 atm pressure?
(a) 0.1 M KCl
(b) 0.1 M Urea
(c) 0.1 M $CaCl_2$
(d) 0.1 M $AlCl_3$

4. People add sodium chloride to water while boiling eggs. This is to
(a) Decrease the boiling point.
(b) Increase the boiling point.
(c) Prevent the breaking of eggs.
(d) Make eggs tasty.

5. The van't Hoff factor (i) accounts for
(a) Degree of solubilisation of solute.
(b) The extent of dissociation of solute.
(c) The extent of dissolution of solute.
(d) The degree of decomposition of solution.

6. The molal elevation constant depends upon
(a) Nature of solute.
(b) Nature of the solvent.
(c) Vapour pressure of the solution.
(d) Enthalpy change

7. The osmotic pressure of a solution is directly proportional to
(a) The molecular concentration of the solute
(b) The absolute temperature at a given concentration
(c) The lowering of vapour pressure
(d) All the above.

8. Which of the following is a colligative property?
(a) Osmotic pressure
(b) Boiling point
(c) Vapour pressure
(d) Electrical conductivity

9. Which of the following 0.1 M aqueous solutions will have the lowest freezing point?
(a) Potassium sulphate
(b) Sodium chloride
(c) Urea
(d) Glucose

10. The mass of $(COOH)_2.\ 2H_2O$ needed to prepare 500dm^3.of 0.1 Molar solution is
(a) 12.6 gm
(b) 6.3 gm
(c) 4.5 gm
(d) 9.0 gm

11. Which of the following solutions has highest osmotic pressure?
(a) 1 M NaCl
(b) 1 M $MgCl_2$
(c) 1 M urea
(d) 1M glucose.

12. Which of the following aqueous solutions containing 10 g of solute in each case, has highest m.pt?
(a) NaCl solution
(b) KC**1**.solution
(c) Sugar solution
(d) Glucose solution.

13. The molal freezing point constant for water is 1.86° CM. The freezing point of 0.1 M NaCl solution is expected to be
(a) -1.86 degree C
(b) -0.372 degree C
(c) -0.186 degree C
(d) 0.372 degree C

14. In case of electrolyte which dissociates in solution the Van't Hoff's factor, i is
(a) > 1
(b) < 1
(c) $= 1$
(d) $= 0$

15. The law stating that the relative lowering of vapour pressure is equal to the mole fraction of a solute in the solution is known as
(a) Henry's law
(b) Van't Hoff, Law
(c) Raoult's law
(d) Ostwald's dilution law

16. Which of the following modes of expressing concentration is independent of temperature?
(a) Molarity
(b) Normality
(c) Formality
(d) Molality

17. A 500 g tooth paste sample has 0.2 g fluoride concentration. What is the concentration of fluorine in terms of ppm level?
(a) 250
(b) 200
(c) 400
(d) 1000

18. The average osmotic pressure of human bipod is 7.8 bar at 37°C. What is the concentration of an aqueous solution of NaCl that could be used in blood stream?
(a) 0.15 Mol L^{-1}
(b) 0.30 Mol L^{-1}
(c) 0.60 Mol L^{-1}
(d) 0.45 Mol L^{-1}

19. Equimolar solutions in the same solvent have
(a) Same B.Pt but different F.Pt
(b) Same F. Pt, but different B.Pts.
(c) Same Boiling and same freezing point
(d) Different boiling and different freezing points.

20. The vapour pressure of the two liquids ‘P’ and ‘Q’ are 80. and 60 torr respectively. The total vapour pressure of the solution obtained by mixing 3 Mol of P and 2 Mole of Q would be
(a) 68 torr
(b) 140 torr
(c) 72 torr
(d) 20 torr

21. If an aqueous solution of glucose is allowed to freeze, then crystals of which substance will be separated and first?
(a) Glucose
(b) Water
(c) Both of these
(d) None of these

22. Two solutions of a substance (non-electrolyte) are mixed in the following mariner: 480 ML of 1.5 M of first solution + 520 ML of 1.2 M second solution. What is the molarity of the final mixture?
(a) 1.20 M
(b) 1.50 M
(c) 1.344 M
(d) 2.70 M

23. If a is the degree of dissociation of Na2SO**4**.the Van’t Hoff factor (i) used for calculating the molecular mass is
(a) $1.+ \alpha$
(b) $1.- \alpha$
(c) $1.+ 2\alpha$
(d) $1.- 2\alpha$

24. X is dissolved in water. Maximum boiling point is observed when X is ……….. (0.1 M each)
(a) $CuSO_4$
(b) $BaCl_2$
(c) NaCl
(d) Urea

25. The mole fraction of the solute in one molal aqueous solution is
(a) 0.027
(b) 0.036
(c) 0.018
(d) 0.019

26. The atmospheric pollution is generally measured in the units of
(a) Mass percentage
(b) Volume percentage
(c) Volume fraction
(d) ppm

27. A 5% solution of cane-sugar (molecular weight = 342) is isotonic with 1% solution of substance A. The molecular weight of X is
(a) 342
(b) 171.2
(c) 68.4
(d) 136.8

28. H2S is a toxic gas used in qualitative analysis. If solubility of H2S in water at STP is 0.195 M. what is the value of KH?
(a) 0.0263 bar
(b) 69.16 bar
(c) 192 bar
(d) 282 bar

29. Atomic mass is equal to
(a) Number of electrons of an atom
(b) Sum of the numbers of electrons and protons of an atom
(c) Sum of the numbers of neutrons and protons of an atom
(d) None of these

30. The law which indicates the relation’-hip between solubility of a gas in liquid and pressure rs
(a) Raoult’s law
(b) Henry’s law
(c) Lowering of vapour pressure
(d) Van’t Hoff law

31. Among the following substances the lowest vapour pressure is exerted by
(a) Water
(b) Alcohol
(c) Ether
(d) Mercury

32. Partial pressure of a solution component is directly proportional to its mole fraction. This is known as
(a) Henry’s law
(b) Raoult’s law
(c) Distribution law
(d) Ostawald’s dilution law

33. Which of the following solutions shows positive deviation from Raoult’s law?
(a) Acetone + Aniline
(b) Acetone + Ethanol
(c) Water + Nitric acid
(d) Chloroform + Benzene

34. The system that forms maximum boiling azetrope is
(a) Acetone-chloroform
(b) ethanol-acetone
(c) n-hexane-n-heptane
(d) carbon disulphide-acetone

35. A plant cell shrinks when it is kept in a
(a) Hypotonic solution
(b) Hypertonic solution
(c) Isotonic solution
(d) Pure water

36. The relative lowering in vapour pressure is proportional to the ratio of number of
(a) Solute molecules to solvent molecules
(b) Solvent molecules to solute molecules
(c) Solute molecules to the total number of molecules in solution
(d) Solvent molecules to the total number of molecules in solution

37. The osmotic pressure of a solution can be increased by
(a) Increasing the volume
(b) Increasing the number of solute molecules
(c) Decreasing the temperature
(d) Removing semipermeable membrane

38. Sprinkling of salt helps in clearing the snow covered roads in hills. The phenomenon involved in the process is
(a) Lowering in vapour pressure of snow
(b) Depression in freezing point of snow
(c) Melting of ice due to increase in temperature by putting salt
(d) Increase in freezing point of snow

39. For carrying reverse osmosis for desalination of water the material used for making semipermeable membrane is
(a) Potassium nitrate (b) Parchment membrane
(c) Cellulose acetate (d) Cell membrane

40. At equilibrium the rate of dissociation of a solid solute in a volatile liquid solvent is
(a) Less than the rate of crystallisation
(b) Greater than the rate of crystallisation
(c) Equal to the rate of crystallisation
(d) Zero

41. Which of the following fluoride is used as rat poison?
(a) CaF_2 (b) KF
(c) NaF (d) MgF_2

42. Most of the processes in our body occur in
(a) Solid solution
(b) Liquid solution
(c) Gaseous solution
(d) Colloidal solution

43. The term homogenous mixtures signifies that
(a) Its composition is uniform throughout the mixture.
(b) Its properties are uniform throughout the mixture.
(c) Both composition and properties are uniform throughout the mixture.
(d) Neither composition nor properties are uniform throughout the mixture.

44. Which of the following is a quantitative description of the solution?
(a) Dilute (b) Concentrated
(c) Saturated (d) Molar

45. When a solute is present in trace quantities the following expression is used
(a) Gram per million (b) Milligram percent
(c) Microgram percent (d) Parts per million

46. What weight of glycerol should be added to 600 g of water in order to lower its freezing point by 10°C ?
(a) 496 g (b) 297 g
(c) 310 g (d) 426 g

47. What will be the degree of dissociation of 0.1 M $Mg(NO_3)_2$. solution if van't Hoff factor is 2.74?
(a) 75% (b) 87%
(c) 100% (d) 92%

48. If 2 gm of NaOH is present is 200 Ml of its solution, its molarity will be
(a) 0.25 (b) 0.5
(c) 5 (d) 10

49. From the below options, choose the correct example for gaseous solutions.
(a) Oxygen dissolved in water
(b) Camphor in nitrogen gas
(c) Carbon dioxide dissolved in water
(d) Hydrogen in palladium

50. Maximum amount of a solid solute that can be dissolved in a specified amount of a given liquid solvent does not depend upon _______.
(a) Temperature (b) Nature of solute
(c) Pressure (d) Nature of solvent

ASSERTION AND REASON

Q1. **Assertion:** Molarity of a solution in liquid state changes with temperature.
Reason: The volume of a solution changes with change in temperature.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

Q2. **Assertion:** If a liquid solute more volatile than the solvent is added to the solvent, the vapour pressure of the solution may increase i.e., $p_s > p_o$.
Reason: In the presence of a more volatile liquid solute, only the solute will form the vapours and solvent will not.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

Q3. **Assertion:** If one component of a solution obeys Raoult's law over a certain range of composition, the other component will not obey Henry's law in that range.
Reason: Raoult's law is a special case of Henry's law.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

Q4. **Assertion:** Azeotropic mixtures are formed only by non-ideal solutions and they may have boiling points either greater than both the components or less than both the components.
Reason: The composition of the vapour phase is same as that of the liquid phase of an azeotropic mixture.
(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.
(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.
(c) If the Assertion is correct but Reason is incorrect.
(d) If both the Assertion and Reason are incorrect.

TRUE AND FALSE

Q1. For the same solution, the elevation in boiling point has higher values than depression in freezing point.
(a) True (b) False

Q2. A mixture of benzene and toluene is an ideal solution.
(a) True (b) False

Q3. For an ideal solution, ΔVmixing ≠ 0.
(a) True (b) False.

PRACTICE QUESTIONS (MCQ)

Q1. Which of the following is not an example of a non-ideal solution showing negative deviation?
(a) Carbon tetrachloride + Toluene
(b) HNO_3 + Water
(c) HCl + Water
(d) Acetic acid + Pyridine

Q2. Which of the following is not an example of an Ideal solution?
(a) Benzene + Toluene
(b) n-Hexane + n-Heptane
(c) Ethyl alcohol + Water
(d) Ethyl bromide + Ethyl chloride

Q3. If 2 L, 4 L and 6 L of three separate solutions of concentrations 1 M, 2 M and 3 M, respectively, are mixed together then what is the concentration of the resultant mixture?
(a) 1.500 M (b) 2.333 M
(c) 6.000 M (d) 3.333 M

Q4. What is a solution called when the concentration of the solute equals its solubility in the solvent?
(a) Dilute
(b) Saturated
(c) Unsaturated
(d) Supersaturated

Q5. What is the molality of a solution formed when 58.5g of NaCl is dissolved in 2000 mL of water?
(a) 0.2925 m (b) 29.2500 m
(c) 0.5000 m (d) 0.0005 m

Q6. In a saturated solution with endothermic dissolution, how does the concentration of dissolved solute change with increasing then decreasing temperature?
(a) Keeps increasing
(b) Keeps decreasing
(c) Increases and decreases
(d) Decreases and increases

Q7. Calculate the mole fraction of A if 25g of it is dissolved in 50 moles of B. Given the molar mass of A is 25 g/mole.
(a) 0.9259 (b) 0.0196
(c) 0.5000 (d) 0.3333

Q8. What is the molarity of a 15 ml, 2 M aqueous solution when 285 ml of water is added to it?
(a) 0.105 M (b) 0.400 M
(c) 0.100 M (d) 0.111 M

Q9. Consider 100 ml of 0.3 molar solution formed by dissolving 3.33g of XCl_2 in water. What is the molar mass of element X? (Atomic mass of Cl = 35.5)
(a) 9 (b) 24
(c) 40 (d) 87

Q10. Iron (III) oxide chunks contain 80 ppm silica (SiO_2). What is the concentration of this impurity in mass%?
(a) 8.000% (b) 0.008%
(c) 0.080% (d) 0.800%

Q11. What is the mole fraction of glycerin $C_3H_5(OH)_3$ in a solution containing 33g of glycerin, 60g isopropyl alcohol and rest water?
(a) 0.359 (b) 0.258
(c) 0.205 (d) 0.480

Q12. What is the normality of lead (II) nitrate if the density of its 26% (w/w) aqueous solution is 3.105 g/mL? Take molar mass of lead (II) nitrate to be 331g/mol.
(a) 0.488 N
(b) 2.437 N
(c) 4.878 N
(d) 0.243 N

Q13. What is the observation on adding a solute crystal to a supersaturated solution?
(a) The solute precipitates out of the solution
(b) It becomes a colloidal solution
(c) The solute dissolves in the solution
(d) The solution desaturates

Q14. What is pumice stone an example of?
(a) Solid aerosol (b) Emulsion
(c) Liquid aerosol (d) Solid foam

Q15. Which of the following is a true solution?
(a) Starch solution (b) Salt solution
(c) Ink (d) Blood

Q16. What is camphor in N_2 gas an example of?
(a) Gas in gas solution
(b) Solid in liquid solution
(c) Liquid in gas solution
(d) Solid in gas solution

Q17. What is an alloy of copper and zinc called?
(a) Solder (b) Bronze
(c) German silver (d) Brass

Q18. Which of the following is not a solid solution?
(a) Brass (b) Bronze
(c) Hydrated salts (d) Aerated drinks

Q19. Acetic acid associates as dimers in benzene. What is the Van't Hoff factor (i) if the degree of association of acetic acid is 50%?

(a) 0.40 (b) 0.25

(c) 0.50 (d) 0.75

Q20. The pH of a 2 M solution of a weak monobasic acid (H_A) is 4. What is the value of the Van't Hoff factor?

(a) 1.00005 (b) 0.00005

(c) 1.005 (d) 1.0005

Q21. Osmotic pressure of 0.4% urea solution is 1.64 atm and that of 3.42% cane sugar is 2.46 atm. When the above two solutions are mixed, the osmotic pressure of the resulting solution is

(a) 0.82 atm (b) 2.06 atm

(c) 1.64 tm (d) 4.10 atm

Q22. Relative lowering of vapour pressure of a dilute solution is 0.2. What is the mole fraction of the non-volatile solute?

(a) 0.8 (b) 0.5

(c) 0.3 (d) 0.2

Q23. Depression in freezing point is 6 K for NaCl solution if k_f for water is 1.86 K/kg/mol, amount of NaCl dissolved in 1 kg water is

(a) 3.42 (b) 1.62

(c) 3.24 (d) 1.71

Q24. If a solution containing 0.072 g atom of sulphur in 100 g of a solvent gave a freezing point depression of 0.84 ^{0}C, the molecular formula of sulphur in the solution is

(a) S_6 (b) S_7

(c) S_8 (d) S_9

Q25. The magnitude of colligative properties in all colloidal dispersions is ….than solution

(a) Lower (b) Higher

(c) Both (d) None

Q26. The molar freezing point constant for water is 186^{0}C/mol. If 342 g of cane sugar is dissolved in 1000 g of water, the solution will freeze at

(a) -1.86 ^{0}C (b) 1.86 ^{0}C

(c) 3.92 ^{0}C (d) 2.42 ^{0}C

Q27. The movement of solvent molecules through a semipermeable membrane is called

(a) Electrolysis

(b) Electrophoresis

(c) Osmosis

(d) Cataphoresis

Q28. The osmotic pressure of 0.2 molar solution of urea at 27^{0}C is

(a) 4.92 atm (b) 1 atm

(c) 0.2 atm (d) 27 atm

Q29. Dry air is passed through a solution containing 10 g of a solute in 90 g of water and then through pure water. The loss in weight of solution is 2.5 g and that of pure solvent is 0.05 g. calculate the molecular weight of the solute.

(a) 50

(b) 180

(c) 100

(d) 25

(e) 51

Q30. Which of the following is correct?

(a) Relative lowering of vapour pressure is independent of the nature of the solute and the solvent

(b) The relative lowering of vapour pressure is a colligative property

(c) Vapour pressure of a solution is lower than the vapour pressure of the solvent

(d) The relative lowering of vapour pressure is directly proportional to the original pressure.

ASSERTION AND REASON

Q1. **Assertion:** When a solution is separated from the pure solvent by a semi- permeable membrane, the solvent molecules pass through it from pure solvent side to the solution side

Reason: Diffusion of solvent occurs from a region of high concentration solution to a region of low concentration solution.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

Q2. **Assertion:** When NaCl is added to water a depression in freezing point is observed.

Reason: The lowering of vapour pressure of a solution causes depression in the freezing point.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

Q3. **Assertion:** When methyl alcohol is added to water, boiling point of water increases.

Reason: When a volatile solute is added to a volatile solvent elevation in boiling point is observed.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

Q4. **Assertion:** 1 M solution of KCl has greater osmotic pressure than 1 M solution of glucose at the same temperature.

Reason: In solution, KCl dissociates to produce more number of particles.

(a) If both Assertion and Reason are correct and the Reason is a correct explanation of the Assertion.

(b) If both Assertion and Reason are correct but Reason is not a correct explanation of the Assertion.

(c) If the Assertion is correct but Reason is incorrect.

(d) If both the Assertion and Reason are incorrect.

TRUE AND FALSE

Q1. A solution shows positive deviation from Raoult's law when A−B molecular interaction forces are stronger thanA−A or B−B interaction forces.
(a) True
(b) False

Q2. Lowering of vapour pressure is a colligative property.
(a) True
(b) false

Q3. The relative lowering of vapour pressure for a solution is equal to the mole fraction of solute present in the solution.
(a) True
(b) False

SOLUTIONS MULTIPLE CHOICE

1. **(c)** m, x
Molality (m) and mole fraction (x) involves only mass and do not depend upon volume. Hence, these are independent of temperature.

2. **(b)** positive deviation from Raoult's Law.
The mixture shows positive deviations from Raoult's law.
Positive deviations from Raoult's law are noticed when
(i) Exp. value of vapour pressure of mixture is more than calculated value.
(ii) Exp. value of b.pt. of mixture is less than calculated value.
(iii) Δ_{mixing} =+ve
(iv) ΔV_{mixing} = +ve

3. **(b)** 0.1 M Urea
as the concentration of all the three compounds are the same, the boiling point will be compared by using the Van't Hoff factor.
The van't hoff factor for the compounds will be as below
KCl : 2
urea : 1
AlCl3 : 4
So the lowest van't hoff factor is of urea and therefore it will have the lowest boiling point.

4. **(b)** increase the boiling point

5. **(d)** the extent of dissociation of solute.
The Van't Hoff's factor 'i' accounts for the extent of dissociation of solute.
For example, one molecule of **NaCl** completely dissociates to produce two ions.
$\mathbf{NaCl \rightarrow Na^+ + Cl^-}$
Hence, its Van't Hoff's factor 'i' is 2.

6. **(b)** nature of the solvent.

7. **(d)** All of the above
π=CRT
From above we can say that,
The molecular concentration of solute
The absolute temperature at a given concentration
The lowering of vapour pressure as it is colligative property and depends on no of the molecule.

8. **(a)** Osmotic pressure
A colligative property is a property of a solution that is dependent on the ratio between the total number of solute particles to the total number of solvent particles. The four colligative properties that can be exhibited by a solution are:
Boiling point elevation
Freezing point depression
Relative lowering of vapour pressure
Osmotic pressure

9. **(a)** Potassium sulphate
Urea and glucose do not dissociate in solution. Sodium chloride gives two ions and potassium sulphate gives three ions per formula unit.
Therefore, the effective number of particles is maximum in potassium sulphate , and it shows the maximum depression in freezing point.

10. **(b)** 6.3 gm

11. **(a)** 1 M NaCl
The colligative ions in Nacl solution will exert the highest osmotic pressure due to a large number of ions.

12. **(c)** Sugar solution
we have, elevation in boiling point
$\Delta T_b = i \times K_b \times m$ among all of the above NaCl have high concentration and on dissociation give two ions, thus it has the highest Boiling point.

13. **(c)** -0.186 degree C

$\Delta T_f = K_f \times m \times i \quad i = 2$ (for $NaCl \rightarrow Na^+ + Cl^-$)

M = 0.1 molal

$K_f = 1.86°C/molal$

$\Delta T_f = I \times 1.86 \times 0.1 = 0.186 \times 2 = 0.372°C$

Therefore, now freezing point = $0 - 0.372°C = -0.372°C$

where i is vant hoff constant/factor.

14. **(a)** >1
We know that,

$$i = \frac{\text{number of molecules after association/dissociation}}{\text{number of molecules before association/dissociation}}$$

After dissociation number of molecules increases. Therefore i >1

15. **(c)** Raoult's law
Raoult's law : According to this law, the partial pressure of any volatile constituents of a solution at a constant temperature is equal to the vapour pressure of pure constituents multiplied by the mole fraction of that constituent in the solution.

16. **(d)** Molality
No. of moles of solute per kg of solvent, molality is independent of temperature

17. **(c)** 400
Mass of solute (i.e. concentration of F^- ion) = 0.2 g in 500 g
Concentration in ppm = weight of fluoride ion (g)/total weight of toothpaste (g) x 10^6
Concentration of fluoride ion in ppm $=0.2/500\times10^6 = 400$ ppm

18. **(a)** 0.15 mol L^{-1}
NaCl should lie isotonic with blood
πblood $=C_{NaCl}$ RT × i

$7.8 = C \times 0.0821 \times 310 \times 2$
$C = 0.153 mole^{-1}$

19. **(c)** Same Boiling and same freezing point
Boiling point and freezing point depend on *Kb* (molal elevation constant) and *Kf* (molal depression constant) of the solvent. Thus equimolar solution (of the non-electrolyte) will have same boiling point and also same freezing point.
$\Delta T_f = K_f \times$ molality
$\Delta T_b = K_b \times$ molality

20. **(c)** 72 torr
The formula for calculating the vapour pressure of a solution is given by:
$P_T = P_P{}^0\chi_P + P_Q{}^0\chi_Q$
Where PT = Vapour pressure of the solution
PP = Vapour pressure of liquid 'P' in pure state
PQ = Vapour pressure of liquid 'Q' in pure state
χP = Mole fraction of liquid P in the solution
χQ = Mole fraction of liquid Q in the solution
In this question,
PP = 80
PQ = 60
moles of P=3 and Q=2 int the solution, So total moles = 5
χP = 0.6
χQ = 0.4
Hence PT = 80 x 0.6 + 60 x 0.4 = S72.

21. **(b)** Water
Freezing point is the temperature at which the liquid and the solid form of the same substance are in equilibrium and hence have the same vapour pressure. Due to lower vapour pressure of the solution, solid form of a solution separates out at a lower temperature. The decrease is called depression in freezing point.

When solid is the solute, it is solvent that freezes. Hence in the given question water will be separated out first.

22. **(c)** 1.344 M

$$\text{Total molarity} = \frac{M_1V_1 + M_2V_2}{V_1 + V_2}$$

$$= \frac{1.5\times480+1.2\times520}{480+520}$$

$$= 1.344\,M$$

23. **(c)** 1 + 2α

$Na_2SO_4 \rightleftharpoons 2Na^{\div} + SO_4^{2-}$

van't Hoff factor $i = [1 + (y - 1)\,\alpha]$

where y is the number of ions from one mole solute, (in this case $= 3$), α the degree of dissociation. $i =$

$(1 + 2\alpha)$

24. **(a)** $BaCl_2$

The Barium chloride will be 0.1 mole L^{-1} with respect to Ba^{2+} but 0.2 mol L^{-1} with respect to Cl^-. Since, Barium chloride solution contains the greatest number of solute particles, we would predict that this solution should exhibit the highest boiling point.

25. **(c)** 0.018

$W = 1000\,g\,(H_2O)\,; n = 1\,mol$

$N = \frac{W}{M} = \frac{1000}{18} = 55.5$

(solute) $= \frac{n}{n+N}$

$= \frac{1}{1\div 55.5} = 0.018$

26. **(d)** ppm

Since the amount of pollutants present in atmosphere is very small, atmospheric pollution is measured in parts per million (ppm)

27. **(c)** S68.4

Given 5% solution of Cane Sugar

⇒5g of solute present in 100ml of solution

For isotonic solutions $\pi_1 = \pi_2$

$\Rightarrow c_1 = c_2$

$$\frac{5}{342 \times 0.1} = \frac{1}{M_2 \times 0.1}$$

M2 = S68.4

28. **(d)** 282 bar

No. of moles of $H_2S = 0.195$

No. of moles of $H_2O = \frac{1000}{18} = 55.55\,mol$

Mole fraction of $H_2S = \frac{0.195}{0.195+55.55} = 0.0035$

Pressure at $STP = 0.987$ bar

According to Henry's law, $p = K_H x$

or $K_H = \frac{p_{H_2S}}{x_{H_2S}} = \frac{0.987}{0.0035}$

$= 282$ bar

29. **(c)** sum of the numbers of neutrons and protons of an atom

Atomic mass of an element is equal to the sum of proton and neutrons.

30. **(b)** Henry's law

Henry's law states that the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas present above the surface of the liquid or solution.

$p=K_{HX}$

31. **(d)** Mercury

Vapor pressure of mercury is very low (compared to a liquid like methyl alcohol) because the forces of interaction between the individual metal atoms of mercury is quite a bit stronger than the cohesive molecular forces (such as a hydrogen bonding) that holds together several molecules in case of alcohols, ethers and water.

32. **(b)** Raoult's law

It is statement of Raoult- law. Mathematically, $P_{\text{solution}} \propto X_{solvent}$

33. **(b)** Acetone + Ethanol

Acetone + ethanol is an example of solutions showing positive deviation from Raoult's law . Since acetone -ethanol attractions are weaker than acetone-acetone and ethanol-ethanol attractions

34. **(a)** Acetone-chloroform

A mixture of chloroform and acetone forms a solution with negative deviation from Raoult's law. This is because chloroform molecule is able to form hydrogen bond with acetone molecule as shown.

This decreases the escaping tendency of molecules for each component and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

The solutions that show large negative deviation from Raoult's law form maximum boiling azeotrope at a specific composition

35. **(b)** hypertonic solution

Hypertonic solution has high osmotic pressure. When a plant cell is placed in hypertonic solution water will diffuse out of the cell resulting in shrinking of the cell.

36. **(c)** solute molecules to the total number of molecules in solution

Relative lowering of vapour pressure. The vapour pressure of a liquid is the pressure of the vapour which is in equilibrium with that liquid. The vapour pressure of a solvent is lowered when a non-volatile solute is dissolved in it to form a solution.

37. **(b)** increasing the number of solute molecules
π = n/V (RT)

38. **(b)** depression in freezing point of snow
When salt is spread over snow covered roads, snow starts melting from the surface because of the depression in freezing point of water and it helps in clearing the roads.

39. **(c)** cellulose acetate
Solubility changes with temperature. A plant cell shrinks in hypertonic solution. Relative lowering of vapour pressure is a colligative property.

40. **(c)** equal to the rate of crystallisation
At equilibrium the rate of dissolution of solid in a volatile liquid solvent is equal to the rate of crystallisation.

41. **(c)** Sodium fluoride is used as rat poison.

42. **(b)** Almost all the processes in our body occur in liquid solution.

43. **(c)** In homogeneous mixtures composition and properties both are uniform throughout the mixture.

S44. **(d)** Dilute, concentrated and saturated terms are qualitative methods of description of concentration of solution whereas molar or molarity is quantitative method.

45. **(d)** parts per million

46. **(b)** 297 g

47. **(b)** 87%

48. **(a)** 0.25

49. **(b)**

50. **(c)** Pressure

ASSERTION AND REASON

1. **(a)** Volume of solutions is a function of temperature which varies with temperature. Hence, molarity of solution in liquid sate changes with temperature.
Molarity = moles of solute / volume of solution in litre

2. **(c)** When a volatile solute is added to volatile solvent then the number of vapors formed will be more as both of them will escape now .Otherwise , if the solute is non-volatile then some surface gets occupied by non-volatile component and escaping tendency decreases
Reason: It is false.
In the presence of volatile solute, solvent can also form vapours.

3. **(b)** Raoult's law holds over the entire concentration range x = 0 to 1 in a binary solution then, for the second component, the same must also hold.

If deviations from the ideal are not too large, Raoult's law is still valid in a narrow concentration range when approaching x = 1. for the majority phase (the solvent) The solute also shows a linear limiting law, but with a different coefficient. This law is known as Henry's Law.

S4. **(b)** Non-ideal solutions with positive deviation i.e., having more vapour pressure than expected, boil at lower temperature while those with negative deviation boil at higher temperature than those of the components.

TRUE AND FALSE

1. **(b)** Hint: Colligative properties: These are properties of solutions that rely on the ratio of the number of solute particles to the number of solvent molecules in a solution.

2. **(a)** When benzene and toluene are mixed, the reaction does not result in any decrease or increase in the intermolecular attractive forces. So, a mixture of benzene and toluene forms an ideal solution.

3. **(b)** In ideal solution, the volume of the solution is the algebric sum of the volumes of the components before mixing. It means there is no change in volume on mixing is zero .i.e. ΔVmix = 0

The solution generally tends to become ideal when they are dilute .It must obey the Raoult's law..

PRACTICE SOLUTIONS

1. **(a)** HNO3 + Water, HCl + Water and Acetic acid + Pyridine are non-ideal solutions showing negative deviations. Carbon tetrachloride + Toluene is an example of non-ideal solution showing positive deviation.

2. **(c)** An ideal solution may be defined as the solution in which no volume change and no enthalpy change take place on mixing the solute and the solvent in any proportion. Ethyl alcohol + Water is a Non-Ideal solution.

3. **(b)** Given,
V1 = 2 L
V2 = 4 L
V3 = 6L
M_1 = 1 M
M_2 = 2 M

M_3 = 3 M
Resultant concentration, MR = $(M_1V_1 + M_2V_2 + M_3V_3)/(V_1 + V_2 + V_3)$
MR = (2 × 1 + 4 × 2 + 6 × 3)/(2 + 4 + 6) = 2.333 M.

4. **(b)** Saturated solutions are those which contain maximum amount of solute that is soluble and cannot be further dissolved. Dilute solutions have a very low concentration of the salt. Unsaturated solutions have concentration of solute lesser than its solubility. Supersaturated solutions contain more amount of solute than how much is soluble in the solvent. In other words, adding more solute to a saturated solution results in a supersaturated solution.

5. **(c)** Given,
Mass of NaCl, m = 58.5 g
Moles of NaCl, n = mass/molar mass
n = 58.5g/(58.5 g/mole) = 1 mole
Molality = moles of solute/mass of solvent (in kg)
Volume of solvent = 2000 ml = 2 L
Mass of solvent = volume × density = 2 L × 1 kg/L = 2 kg

6. **(d)** When a solution is saturated a thermodynamic equilibrium exists between the undissolved solute and dissolved solute. Since the dissolution process here is mentioned as endothermic increasing and decreasing temperatures will decrease and increase the concentration, respectively, as given by Le Chatelier's Principle of equilibrium.

7. **(b)** Given,
Mass of A, mA = 25g
Molar mass of A = 25 g/mole
Number of moles of A, $n_A = m_A/M_A$ = 25/25 = 1 mole
Number of moles of B, n_B = 50 moles
Mole fraction of A, $x_A = n_A/(n_A+n_B)$ = 1/(1 + 50) = 0.0196.

8. **(c)** Given,
Initial concentration, M_1 = 2 M
Initial total volume, V_1 = 15 ml
Final total volume, V_2 = 15 + 285 = 300 ml
Final concentration, M_2 = to be found
Before and after adding water number of moles of solute remain constant since it does not react with water.
Number of moles = concentration × volume
Thus, $M_1 \times V_1 = M_2 \times V_2$
On substituting, M_2 = (2 x 15)/300 = 0.1 M.

9. **(c)** Given,
Concentration, c = 0.3 mole/L
Volume, v = 100 ml = 0.1 L
Number of moles,n = concentration (mole/L) ×volume (L)
n = 0.3 mole/L × 0.1 L = 0.03 moles
0.03 moles of XCl_2 corresponds to 3.33g, then 1 mole contains 3.33/0.03 = 111 g of XCl_2.
Hence, molecular mass = 111 g/mole.
Let x be the atomic mass. Then –
111 = x + 2(35.5)
x = 40g/mole.

10. **(b)** 80 ppm silica means there are 80 mg of silica is 106 mg (or 1 kg) of iron (III) oxide and silica mixture. The mixture can be regarded as 106 mg (or 1 kg) of iron (III) oxide since 80<<106
Mass% = (mass of impurity/mass of total mixture) ×100%
Mass% = (80mg/106mg) × 100% = 0.008%.

11. **(c)** M_w of glycerin = 92g/mol. Number of moles of glycerin = 33/92 = 0.3587 mol
Number of moles of isopropyl alcohol = 60g/(60g/mole) = 1 mole
Number of moles of water = 7g/(18g/mole) = 0.3889 mole
Mole fraction of glycerin = 0.3587/(0.3587 + 1 + 0.3889) = 0.205.

12. **(c)** Consider 100g of solution. It is made up of 26g lead (II) nitrate and 74g water.
Volume of solution, V = 100g/(3.105g/ml) = 32.2061 ml = 0.0322 L
Equivalent weight of lead nitrate = 331/2 = 165.5 g/eq
Number of equivalents, N = 26g/(165.5g/eq) = 0.1571 eq
Normality = N/V = 4.878 N.

13. **(a)** When a solute crystal is added to a supersaturated solution, solute particles leave the solution and forms a crystalline precipitate. The addition of the solute crystal is also called seeding.

14. **(d)** There are 8 types of colloidal solutions namely solid sol, sol, solid aerosol, gel, emulsion, liquid aerosol, solid foam and foam. Pumice stone is a gas in solid type colloidal solution, i.e., solid foam.

15. **(b)** A true solution is a homogeneous mixture of two or more materials with a particle size of less than 10^{-9} m or 1 nm dissolved in the solvent. Ink, blood and starch solution are colloidal solutions. A simple solution of salt in water is a true solution.

16. **(d)** Camphor in N2 gas is an example of solid in gas gaseous solution. A solution in which the solvent is gaseous is called gaseous solution. Some other examples of gaseous solutions are air (O_2 + N_2), Iodine vapours in air, humidity in air, etc.

17. **(d)** An alloy of copper and zinc is called Brass. German silver is an alloy of copper, zinc and nickel, sometimes also containing lead and tin. Bronze is an alloy of copper and tin. Solder is an alloy of tin, lead and antimony.

18. **(d)** A solid solution is a solid-state solution of one or more solutes in a solvent. Brass, bronze, and hydrated salts are examples of solid solutions. Aerated drinks are examples of liquid solutions (gas in liquid).

19. **(d)** Given,
Degree of association (α) = 50% = 0.5
Number of molecules associated (n) = 2
Let the Van't Hoff factor = i
We know that for solutes that associate in solution, i = 1 + ((1/n) -1) × α
= 1 + ((1/2) – 1) × 0.5
= 1 – (0.5 × 0.5)
= 0.75
Therefore, the Van't Hoff factor is equal to 0.75.

20. **(a)** pH = 4 means $[H^+] = 10^{-4}$ M

$$HA \rightleftharpoons H^+ + A^-$$

Initial	C mol L^{-1}	0	0
After dissociation	C - Cα	Cα	Cα

21. **(b)** $\pi = \frac{1.66+2.46}{2} = 2.06 atm$

22. **(d)** According to Raoult's law the relative lowering in vapour pressure of an ideal solution containing the non-volatile solute is equal to the mole fraction of the solute.
∵ Relative lowering of vapour pressure
=0.2
∴ Mole-fraction of the solute =0.2

$\Delta T_f = i \times K_f \times \frac{n}{W} \times 1000$

$i =$ vant Hoff factor

$K_f = 1.86\, K/kg\, mol$

$n =$ number of moles

$W =$ weight of solvent $= 1\, kg = 1000\, g$

$\Delta T_f = 6\, K$ so,

$6 = 2 \times 1.86 \times \frac{n}{1000} \times 10006$

$= 2 = 1.86 \times n$

$n = \frac{6}{1.86} = 1.62$

23. **(b)**

24. **(a)** [HINT] given, mass of solvent = 100 g
Depression in freezing point = 0.84 ^{0}C
$K_f = 7.0$
$\Delta T_f = 1000 \times K_f / n \times w\ (w/M)$

25. **(a)** The magnitude of colligative properties in all colloidal solutions are much lower than solution because colloidal particles exist as aggregates. For a given mass of substance, the number of colloidal particles present in the colloidal solution of the substance will be much less than the number of particles present in its true solution.

26. **(a)** molality of cane sugar 342/342 × 1 = 1 m
$\Delta T_f – K_f.m = 186^0$
$\Delta T_f = Tf^0 – Tf$
$T_f = -186\ ^0C$

27. **(c)** The phenomenon in which, when two solutions of different concentration (one may be solvent) are kept separated by semipermeable membrane, the solvent molecules start flowing from dilute solution to concentrate solution. This is called osmosis. Osmosis is a slow process and keeps on happening until the concentration of both solutions become equal.

28. **(a)**

$$\pi = \frac{0.2 \times 0.082 \times 300}{1.0} = 4.92 \text{ atm.}$$

29. **(c)**

Lowering in weight of solution ∝ solution pressure

Lowering in weight of solvent ∝ $P^0 - P_s$

(∵ p^0 = vapour pressure of pure solvent)

$$\frac{p^0 - p_s}{p_s} = \frac{\text{Lowering in weight of solvent}}{\text{Lowering in weight of solution}}$$

$$\frac{p^0 - p_s}{p_s} = \frac{w \times M}{m \times W}$$

$$\frac{0.05}{2.5} = \frac{10 \times 18}{m \times 90} \Rightarrow m = \frac{2 \times 2.5}{0.05} = \frac{2 \times 250}{5} = 100$$

30. **(d)** According to Raoult's law, the relative lowering in vapour pressure of a dilute solution is equal to mole fraction of the solute present in the solution.

$$\frac{P^0 - P}{P^0} = x_B = \frac{n_B}{n_A}$$

ASSERTION AND REASONING

1. **(b)** When a solution is separated from the pure solvent by a semipermeable membrane, the solvent molecules pass through it from pure solvent side to the solution side. Solvent molecules always flow firm lower concentration to higher concentration of solution.

2. **(a)** When NaCl is added to water a depression in freezing point is observed. This is due to lowering of vapour pressure of a solution. Lowering of vapour pressure is observed due to intermolecular interaction of solvent-solute particles.

3. **(d)** Elevation of boiling-point describes that the boiling point of a liquid (a solvent) will be higher when another compound is added to it, meaning that a solution has a higher boiling point than a pure solvent.

   This happens whenever a non-volatile solute, such as a salt, is added to a pure solvent, such as water.

   When methanol is added to water, the boiling point of water decreases.

   When a more volatile solute is added to the volatile solvent vapour pressure of solvent increases due to an elevation in boiling point colligative property.

4. **(a)**

TRUE AND FALSE

1. **(b)** In case of positive deviation from Raoult's law, A-B interactions are weaker than those between A-A or B-BIn this case the intermolecular attractive forces between the solute-solvent molecules are weaker than those between the solute-solute and solvent-solvent molecules. This means that in such solutions, molecules of A will find it easier to escape than in pure state. This will increase the vapour pressure in positive deviation.

2. **(a)** Relative Lowering of Vapour Pressure depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution. Such properties are called colligative properties. Hence, Lowering of vapour pressure is a colligative property.

3. **(a)** The vapour pressure of a liquid is the pressure of the vapour which is in equilibrium with that liquid. The vapour pressure of a solvent is lowered when a non-volatile solute is dissolved in it to form a solution. The reduction of vapour pressure of solvent is: P = x·po where, P is a vapour pressure of the solution. po is a vapour pressure of the pure solvent. Relative lowering of vapour pressure is $P/p_0 = x$

   Where x is mole fraction of solute .Hence, the relative lowering of vapour pressure for a solution is equal to the mole fraction of solute present in the solution