CHAPTER

2

Solutions

CASE STUDY / PASSAGE BASED QUESTIONS

Syllabus

Types of solutions, expression of concentration of solutions of solids in liquids, solubility of gases in liquids, solid solutions, Raoult's law, colligative properties- relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmotic pressure, determination of molecular masses using colligative properties.

1

Read the passage given below and answer the following questions :

The concentration of a solute is very important in studying chemical reactions because it determines how often molecules collide in solution and thus indirectly determine the rate of reactions and the conditions at equilibrium.

There are several ways to express the amount of solute present in a solution. The concentration of a solution is a measure of the amount of solute that has been dissolved in a given amount of solvent or solution. Concentration can be expressed in terms of molarity, molality, parts per million, mass percentage, volume percentage, etc.

The following questions are multiple choice questions. Choose the most appropriate answer :

(i) A solution is prepared using aqueous KI which is turned out to be 20% *w*/*w*. Density of KI is 1.202 g/mL. The molality of the given solution and mole fraction of solute are respectively

(a) 1.95 m, 0.120
(b) 1.5 m, 0.0263
(c) 2.5 m, 0.0569
(d) 3.0 m, 0.0352

OR

The molarity (in mol L^{-1}) of the given solution will be

(a) 1.56
(b) 1.89
(c) 0.263
(d) 1.44

(ii) Which of the following is correct relationship between mole fraction and molality?

(a) $x_2 = \frac{mM_1}{1+mM_1}$
(b) $x_2 = \frac{mM_1}{1-mM_1}$
(c) $x_2 = \frac{1+mM_1}{mM_1}$
(d) $x_2 = \frac{1-mM_1}{mM_1}$

(iii) Which of the following is temperature dependent?

(a) Molarity
(b) Molality
(c) Mole fraction
(d) Mass percentage

(iv) Which of the following is true for an aqueous solution of the solute in terms of concentration?

(a) $1\text{ M} = 1\text{ m}$
(b) $1\text{ M} > 1\text{ m}$
(c) $1\text{ M} < 1\text{ m}$
(d) Cannot be predicted

2

Read the passage given below and answer the following questions :

At 298 K, the vapour pressure of pure benzene, C_6H_6 is 0.256 bar and the vapour pressure of pure toluene $C_6H_5CH_3$ is 0.0925 bar. Two mixtures were prepared as follows :

(I) 7.8 g of C_6H_6 + 9.2 g of toluene

(II) 3.9 g of C_6H_6 + 13.8 g of toluene

The following questions are multiple choice questions. Choose the most appropriate answer :

(i) The total vapour pressure (bar) of solution I is

(a) 0.128 (b) 0.174 (c) 0.198 (d) 0.258

(ii) Which of the given solutions have higher vapour pressure?

(a) I (b) II

(c) Both have equal vapour pressure (d) Cannot be predicted

(iii) Mole fraction of benzene in vapour phase in solution I is

(a) 0.128 (b) 0.174 (c) 0.734 (d) 0.266

(iv) Which of the following statements is/are correct?

(I) Mole fraction of toluene in vapour phase is more in solution I.

(II) Mole fraction of toluene in vapour phase is less in solution I.

(III) Mole fraction of benzene in vapour phase is less in solution I.

(a) Only II (b) Only I (c) I and III (d) II and III

OR

Solution I is an example of a/an

(a) ideal solution (b) non-ideal solution with positive deviation

(c) non-ideal solution with negative deviation (d) can't be predicted.

3

Read the passage given below and answer the following questions :

An ideal solution may be defined as the solution which obeys Raoult's law exactly over the entire range of concentration. The solutions for which vapour pressure is either higher or lower than that predicted by Raoult's law are called non-ideal solutions.

Non-ideal solutions can show either positive or negative deviations from Raoult's law depending on whether the $A–B$ interactions in solution are stronger or weaker than $A – A$ and $B – B$ interactions.

The following questions are multiple choice questions. Choose the most appropriate answer :

(i) Which of the following solutions is/are ideal solution(s)?

(I) Bromoethane and iodoethane (II) Acetone and chloroform

(III) Benzene and acetone (IV) *n*-heptane and *n*-hexane

(a) only I (b) I and II (c) II and III (d) I and IV

OR

For which of the following solutions ΔH_{mix} and ΔV_{mix} is negative?

(a) Acetone and aniline (b) Ethyl alcohol and cyclohexane

(c) Acetone and CS_2 (d) Benzene and toluene

(ii) Which of the following is not true for positive deviations?

(a) The A–B interactions in solution are weaker than the A –A and B –B interactions.

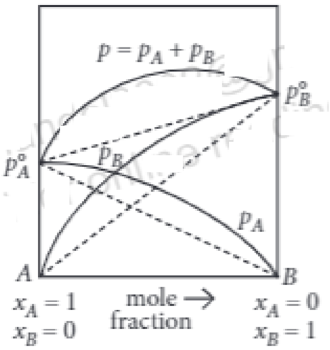
(b) $P_A < P_A^\circ x_A$ and $P_B < P_B^\circ x_B$

(c) Carbon tetrachloride and chloroform mixture is an example of positive deviations.

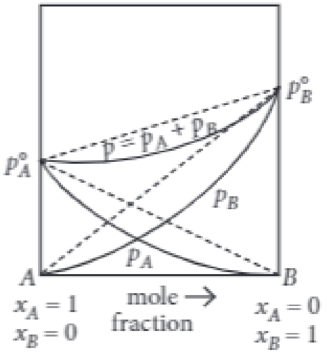
(d) All of these.

(iii) For water and nitric acid mixture which of the given graph is correct?

(a)



(b)



(c) Both of these

(d) None of these

(iv) Water-HCl mixture

I. shows positive deviations

II. forms minimum boiling azeotrope

III. shows negative deviations

IV. forms maximum boiling azeotrope

(a) I and II

(b) II and III

(c) I and IV

(d) III and IV

4

Read the passage given below and answer the following questions :

The properties of the solutions which depend only on the number of solute particles but not on the nature of the solute are called colligative properties. Relative lowering in vapour pressure is also an example of colligative properties.

For an experiment, sugar solution is prepared for which lowering in vapour pressure was found to be 0.061 mm of Hg. (Vapour pressure of water at 20°C is 17.5 mm of Hg.)

The following questions are multiple choice questions. Choose the most appropriate answer :

(i) Relative lowering of vapour pressure for the given solution is

(a) 0.00348 (b) 0.061 (c) 0.122 (d) 1.75

(ii) The vapour pressure (mm of Hg) of solution will be

(a) 17.5 (b) 0.61 (c) 17.439 (d) 0.00348

(iii) Mole fraction of sugar in the solution is

(a) 0.00348 (b) 0.9965 (c) 0.061 (d) 1.75

OR

If weight of sugar taken is 5 g in 108 g of water then molar mass of sugar will be

(a) 358 (b) 120 (c) 240 (d) 400

(iv) The vapour pressure (mm of Hg) of water at 293 K when 25 g of glucose is dissolved in 450 g of water is

(a) 17.2 (b) 17.4 (c) 17.120 (d) 17.02

5

Read the passage given below and answer the following questions :

Few colligative properties are :

(a) relative lowering of vapour pressure : depends only on molar concentration of solute (mole fraction) and independent of its nature.

(b) depression in freezing point : it is proportional to the molal concentration of solution.

(c) elevation of boiling point : it is proportional to the molal concentration of solute.

(d) osmotic pressure : it is proportional to the molar concentration of solute.

A solution of glucose is prepared with 0.052 g at glucose in 80.2 g of water. (K_f = 1.86 K kg mol^{-1} and K_b = 5.2 K kg mol^{-1})

The following questions are multiple choice questions. Choose the most appropriate answer :

(i) Molality of the given solution is
(a) 0.0052 m
(b) 0.0036 m
(c) 0.0006 m
(d) 1.29 m

(ii) Boiling point for the solution will be
(a) 373.05 K
(b) 373.15 K
(c) 373.02 K
(d) 372.98 K

(iii) The depression in freezing point of solution will be
(a) 0.0187 K
(b) 0.035 K
(c) 0.082 K
(d) 0.067 K

(iv) Mole fraction of glucose in the given solution is
(a) 6.28×10^{-5}
(b) 1.23×10^{-4}
(c) 0.00625
(b) 0.00028

OR

If same amount of sucrose ($C_{12}H_{22}O_{11}$) is taken instead of glucose then
(a) elevation in boiling point will be higher
(b) depression in freezing point will be higher
(c) depression in freezing point will be lower
(d) both (a) and (b)

6

Read the passage given below and answer the following questions :

The solubility of gases increases with increase of pressure. William Henry made a systematic investigation of the solubility of a gas in a liquid. According to Henry's law "the mass of a gas dissolved per unit volume of the solvent at constant temperature is directly proportional to the pressure of the gas in equilibrium with the solution". Dalton during the same period also concluded independently that the solubility of a gas in a liquid solution depends upon the partial pressure of the gas. If we use the mole fraction of gas in the solution as a measure of its solubility, then Henry's law can be modified as "the partial pressure of the gas in the vapour phase is directly proportional to the mole fraction of the gas in the solution".

The following questions are multiple choice questions. Choose the most appropriate answer :

(i) Henry's law constant for the solubility of methane in benzene at 298 K is 4.27×10^5 mm Hg. The solubility of methane in benzene at 298 K under 760 mm Hg is
(a) 4.27×10^{-5}
(b) 1.78×10^{-3}
(c) 4.27×10^{-3}
(d) 1.78×10^{-5}

(ii) The partial pressure of ethane over a saturated solution containing 6.56×10^{-2} g of ethane is 1 bar. If the solution contains 5.00×10^{-2} g of ethane then what will be the partial pressure (in bar) of the gas?

(a) 0.762 (b) 1.312 (c) 3.81 (d) 5.0

(iii) K_H (K bar) values for $Ar_{(g)}$, $CO_{2(g)}$, $HCHO_{(g)}$ and $CH_{4(g)}$ are 40.39, 1.67, 1.83×10^{-5} and 0.413 respectively. Arrange these gases in the order of their increasing solubility.

(a) $HCHO < CH_4 < CO_2 < Ar$ (b) $HCHO < CO_2 < CH_4 < Ar$

(c) $Ar < CO_2 < CH_4 < HCHO$ (d) $Ar < CH_4 < CO_2 < HCHO$

(iv) When a gas is bubbled through water at 298 K, a very dilute solution of the gas is obtained. Henry's law constant for the gas at 298 K is 150 kbar. If the gas exerts a partial pressure of 2 bar, the number of millimoles of the gas dissolved in 1 L of water is

(a) 0.55 (b) 0.87 (c) 0.37 (d) 0.66

OR

Which of the following statements is correct?

(a) K_H increases with increase of temperature

(b) K_H decreases with increase of temperature

(c) K_H remains constant with increase of temperature

(d) K_H first increases then decreases, with increase of temperature.

7

Read the passage given below and answer the following questions :

At the freezing point of a solvent, the solid and the liquid are in equilibrium. Therefore, a solution will freeze when its vapour pressure becomes equal to the vapour pressure of the pure solid solvent.

It has been observed that when a non-volatile solute is added to a solvent, the freezing point of the solution is always lower than that of the pure solvent. Depression in freezing point can be given as, $\Delta T_f = K_f m$

Where, K_f = Molal freezing point depression constant

or we can write, $\Delta T_f = \dfrac{K_f \times W_B \times 1000}{W_A \times M_B}$

In these questions (Q. No. i-iv), a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

(c) Assertion is correct statement but reason is wrong statement.

(d) Assertion is wrong statement but reason is correct statement.

(i) **Assertion :** 0.1 M solution of glucose has same depression in the freezing point as 0.1 M solution of urea.
Reason : K_f for both has same value.

OR

Assertion : Increasing pressure on pure water decreases its freezing point.
Reason : Density of water is maximum at 273 K.

(ii) **Assertion :** Larger the value of cryoscopic constant of the solvent, lesser will be the freezing point of the solution.
Reason : Extent of depression in the freezing point depends on the nature of the solvent.

(iii) **Assertion :** The water pouch of instant cold pack for treating athletic injuries breaks when squeezed and NH_4NO_3 dissolves thus lowering the temperature.
Reason : Addition of non-volatile solute into solvent results into depression of freezing point of solvent.

(iv) **Assertion :** If a non-volatile solute is mixed in a solution then elevation in boiling point and depression in freezing point both will be same.
Reason : Elevation in boiling point and depression in freezing point both depend on number of particles of solute.

8

Read the passage given below and answer the following questions :

According to Raoult's law, the partial pressure of two components of the solution may be given as :

$$p_A = p_A^o x_A \text{ and } p_B = p_B^o x_B$$

For an ideal solution (obeys Raoult's law always)

$$\Delta H_{mix} = 0, \Delta V_{mix} = 0$$

All solutions do not obey Raoult's law over entire range of concentration. These are known as non-ideal solutions.

For non-ideal solutions, $p_A \neq p_A^o x_A$ or $p_B \neq p_B^o x_B$

Positive deviation $\Rightarrow p_A > p_A^o x_A$ and $p_B > p_A^o x_B$

Negative deviation $\Rightarrow p_A < p_A^o x_A$ and $p_B < p_B^o x_B$

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(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(c) Assertion is correct statement but reason is wrong statement.
(d) Assertion is wrong statement but reason is correct statement.

(i) **Assertion :** An ideal solution obeys Raoult's law.
Reason : In an ideal solution, solute-solute as well as solvent-solvent interactions are similar to solute-solvent interactions.

(ii) **Assertion :** Acetone and aniline show negative deviations.
Reason : H–bonding between acetone and aniline is stronger than that between acetone-acetone and aniline-aniline.

(iii) **Assertion :** Azeotropic mixtures are formed only by non-ideal solutions and they may have boiling points either greater than both the components or lesser than both the components.
Reason : The composition of the vapour phase is same as that of the liquid phase of an azeotropic mixture.

OR

Assertion : The solutions which show negative deviations from Raoult's law are called maximum boiling azeotropes.
Reason : 68% nitric acid and 32% water by mass form maximum boiling azeotrope.

(iv) **Assertion :** ΔH_{mix} and ΔV_{mix} are positive for an ideal solution.
Reason : The interactions between the particles of the components of an ideal solution are almost identical as between particles in the liquids.

9

Read the passage given below and answer the following questions :

The phenomenon of the flow of solvent through a semipermeable membrane from pure solvent to the solution is called osmosis.

Sometimes a pressure is applied to stop the process of osmosis, this is known as osmotic pressure. It is denoted by π. Osmotic pressure is expressed as : $\pi = CRT$

Since, osmotic pressure depends upon the molar concentration of solution, therefore it is a colligative property.

In these questions (Q. No. i-iv), a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(c) Assertion is correct statement but reason is wrong statement.
(d) Assertion is wrong statement but reason is correct statement.

(i) **Assertion :** If red blood cells were removed from the body and placed in pure water, pressure inside the cells increases.
Reason : The concentration of salt content in the cells increases.

OR

Assertion : The osmotic pressure of a solution obtained by mixing 100 mL of 3.4% solution of urea and 100 mL of 1.6% solution of cane sugar at 293 K is 7.46 bar.
Reason : The total osmotic pressure will be equal to the sum of partial osmotic pressures.

(ii) **Assertion :** 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.
Reason : Diffusion of solvent occurs from a region of high concentration to a region of low concentration solution.

(iii) **Assertion :** Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.
Reason : Osmotic pressure is not a colligative property.

(iv) **Assertion :** The preservation of meat by salting and fruits by adding sugar protects against bacterial action.
Reason : A bacterium on salted meat or candid fruit loses water due to osmosis shrivels and ultimately dies.

10

Read the passage given below and answer the following questions :

If some solute is added to a solvent, the boiling point of solution increases. This is known as elevation in boiling point.

$\Delta T_b = K_b m$ where, K_b = Molal elevation constant
$\Delta T_b \propto m$

Hence, it is a colligative property.

Also, $K_b = \dfrac{MRT_b^2}{\Delta_{\text{vap}}H \times 1000}$

where, M = Molar mass of solvent
$\Delta_{\text{vap}} H$ = Enthalpy of vaporisation

Molar mass can also be calculated using elevation in boiling point.

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

In these questions (Q. No. i-iv), a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(c) Assertion is correct statement but reason is wrong statement.
(d) Assertion is wrong statement but reason is correct statement.

(i) **Assertion :** In a pressure cooker, the water is brought to boil. The cooker is then removed from the stove. Now on removing the lid of pressure cooker, the water starts boiling again.
Reason : The impurities in water bring down its boiling point.

(ii) **Assertion :** On dissolving 3.24 g of sulphur in 40 g of benzene, boiling point of solution get higher than that of benzene by 0.081 K, then the formula of sulphur is S_8. (K_b for benzene = 2.53 K kg mol^{-1})
Reason : Molecular mass of sulphur comes out to be 253.

(iii) **Assertion :** When sugar is added to water, boiling point of water increases.
Reason : When a non-volatile solute is added to a solvent, elevation in boiling point is observed.

(iv) **Assertion :** Cooking time in pressure cookers is reduced.
Reason : Boiling point inside the pressure cooker in raised.

OR

Assertion : Elevation in boiling point of two isotonic solutions is same.
Reason : Boiling point depends upon the concentration of the solute.

ASSERTION & REASON

In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(c) Assertion is correct statement but reason is wrong statement.
(d) Assertion is wrong statement but reason is correct statement.

11. **Assertion :** A solution is a homogeneous mixture of two or more chemically non-reacting substances.
Reason : Solutions can be made between any two states of matter.

12. **Assertion :** Amalgam is a homogeneous solution.
Reason : Amalgam is a solution in which mercury is solute and zinc is solvent.

13. **Assertion :** One molal aqueous solution of urea contains 60 g of urea in 1 kg of water.
Reason : Solution containing one mole of solute in 1000 g solvent is called one molal solution.

14. **Assertion :** The molality of the solution does not change with change in temperature.
Reason : The molality is expressed in units of moles per 1000 g of solvent.

15. **Assertion :** Dilute solution of benzene and toluene is an ideal solution.
Reason : Benzene and toluene form H-bonding with each other.

16. **Assertion :** The pressure exerted by the vapour in equilibrium with a liquid at a given temperature is called its vapour pressure.
Reason : If a non-volatile solute is added to a solvent to give a solution, the vapour pressure of the solution is found to be greater than the vapour pressure of the pure solvent.

17. **Assertion :** Sodium chloride used to clear snow on the roads.
Reason : Sodium chloride depresses the freezing point of water.

18. **Assertion :** Solutions show deviations from Raoult's law.
Reason : The cause for these deviations lies in the nature of interactions at the molecular level.

19. **Assertion :** The vapour pressure of a liquid decreases if some non-volatile solute is dissolved in it.
Reason : The relative lowering of vapour pressure of a solution containing a non-volatile solute is equal to the mole fraction of the solute in the solution.

20. **Assertion :** Osmotic pressure is a colligative property.
Reason : Osmotic pressure depends only on the number of particles dissolved in solution.

21. **Assertion :** Water boils at 373 K as the vapour pressure at this temperature becomes equal to atmospheric pressure.
Reason : Vapour pressure of water is less than 1.013 bar at 373 K.

22. **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.*, $p_s > p°$.
Reason : In the presence of a more volatile liquid solute, only the solute will form the vapours and solvent will not.

23. **Assertion :** If blood cells are placed in pure water, they swell and burst.
Reason : Due to osmosis, the movement of water molecules into the cell, dilutes the salt content.

24. **Assertion :** Solutions having the same osmotic pressure are called isotonic solutions.
Reason : Ca^{2+} and K^+ ions are responsible for maintaining proper osmotic pressure balance in the cells of organism.

25. **Assertion :** If more and more non-volatile solute is added to a solvent, the freezing point of the solution keeps on becoming higher and higher.
Reason : Presence of large amount of the solid solute allow the solution to freeze more rapidly.

26. **Assertion :** When a concentrated solution is diluted by adding more water, the number of moles of solute in the solution remains unchanged.
Reason : Number of moles of a solute is equal to the product of molarity and volume of solution in litres.

27. **Assertion :** The boiling point of 200 mL of 1 M urea solution is less than that of 200 mL of 2 M glucose solution.
Reason : Elevation of boiling point is directly proportional to the number of species present in the solution.

28. **Assertion :** Elevation in boiling point and depression in freezing point are colligative properties.
Reason : All colligative properties are used for the calculation of molecular masses.

29. **Assertion :** Reverse osmosis is used in the desalination of sea water.
Reason : When pressure more than osmotic pressure is applied, pure water is squeezed out of the sea water through the membrane.

30. **Assertion :** Camphor is used as a solvent in the determination of molecular masses of naphthalene, anthracene, etc.
Reason : Camphor has high molal elevation constant.

HINTS & EXPLANATIONS

1. **(i) (b):** Molar mass of KI = 166 g/mol

$$n_{\text{KI}} = \frac{20}{166} = 0.12 \text{ mol}$$

$$\text{Molality} = \frac{n_{\text{KI}}}{w_{\text{H}_2\text{O}}} \times 1000 = \frac{0.12}{80} \times 1000 = 1.5 \text{ m}$$

$$n_{\text{KI}} = 0.12 \text{ and } n_{\text{water}} = \frac{80}{18} = 4.44$$

$$x_{\text{KI}} = \frac{n_{\text{KI}}}{n_{\text{KI}} + n_{\text{H}_2\text{O}}} = \frac{0.12}{0.12 + 4.44} = 0.0263$$

OR

(d) : Density of solution = 1.202 g/mL

$$\text{Volume of solution } = \frac{100 \text{ g}}{1.202 \text{ g/mL}} = 83.2 \text{ mL}$$

$$\text{Molarity} = \frac{n_{\text{KI}}}{\text{Volume of solution in L}}$$

$$= \frac{0.120 \text{ mol}}{0.0832 \text{ L}} = 1.4423 \text{ mol L}^{-1}$$

(ii) (a) : $x_2 = \frac{n_2}{n_1 + n_2}$; $x_1 = \frac{n_1}{n_1 + n_2}$; $\frac{x_2}{x_1} = \frac{n_2}{n_1}$

$$\frac{x_2}{x_1} = \frac{m_2 / M_2}{m_1 / M_1} = \frac{m_2}{m_1} \times \frac{M_1}{M_2} \quad \text{...(i)}$$

$$\text{Molality} = \frac{n_2}{m_1} = \frac{m_2}{M_2 \times m_1} \quad \text{...(ii)}$$

From (i) and (ii), $m = \frac{x_2}{x_1} \times \frac{1}{M_1}$; $x_1 = 1 - x_2$

Hence, $x_2 = \frac{mM_1}{1 + mM_1}$

(iii) (a): Mass does not depend on temperature while volume does. Hence, molarity depends on temperature.

(iv) (b): 1 M solution contains 1 mole of solute in less than 1000 g of the solvent whereas 1 m solution has 1 mole of the solute in 1000 g of the solvent.

2. **(i) (b) :** Moles of $C_6H_6 = \frac{7.8}{78} = 0.1$

Moles of $C_6H_5CH_3 = \frac{9.2}{92} = 0.1$

Mole fraction of $C_6H_6 = \frac{0.1}{0.1 + 0.1} = 0.5$

$\Rightarrow$ Mole fraction of $C_6H_5CH_3 = 0.5$

Vapour pressure of toluene = Vapour pressure of pure toluene × mole fraction of toluene

$$= 0.0925 \times 0.5 = 0.04625$$

Vapour pressure of benzene = 0.256 × 0.5 = 0.128

Total vapour pressure of solution = 0.17425

(ii) (a): Moles of benzene in solution-II $= \frac{3.9}{78} = 0.05$

Moles of toluene in solution-II $= \frac{13.8}{92} = 0.15$

Vapour pressure of solution

$$= 0.256 \times 0.05 + 0.0925 \times 0.15$$
$$= 0.0128 + 0.013875 = 0.026675$$

(iii) (c) : Mole fraction of benzene in vapour phase

$$y_{\text{benzene}} = \frac{p_{\text{benzene}}}{P_{\text{total}}} = \frac{0.128}{0.17425} = 0.734$$

(iv) (a): Mole fraction of toluene in vapour phase in solution-I $= \frac{0.04625}{0.17425} = 0.2654$

Mole fraction of toluene in vapour phase in solution-II

$$= \frac{0.013875}{0.026675} = 0.520$$

Mole fraction of toluene in vapour phase in solution-II is greater than in solution-I.

Hence, statement II is correct.

Mole fraction of benzene in vapour phase in solution – I = 0.734

Mole fraction of benzene in vapour phase in solution-II $= \frac{0.0128}{0.026675} = 0.479$

Thus, mole fraction of benzene in vapour phase is less in solution-II.

OR

(a) : Benzene and toluene form an ideal solution.

3. **(i) (d) :** II represents negative deviations and III represents positive deviations.

OR

(a) : Acetone and aniline mixture represents negative deviations from Raoult's law hence for this mixture, ΔH_{mix} and ΔV_{mix} is negative.

(ii) (b): For positive deviations $p_A > p_A^\circ x_A$ and $p_B > p_B^\circ x_B$

(iii) (b): Water and nitric acid mixture shows negative deviations from Raoult's law, hence

$$p_A < p_A^\circ x_A \text{ and } p_B < p_B^\circ x_B$$

(iv) (d): Water–HCl mixture shows negative deviations from Raoult's law and solutions showing negative deviations from ideal behaviour form maximum boiling azeotrope.

4. **(i) (a) :** Vapour pressure of water (p_A°) = 17.5 mm of Hg

Lowering of vapour pressure ($p_A^\circ - p_A$) = 0.061
Relative lowering of vapour pressure

$$= \frac{p_A^\circ - p_A}{p_A^\circ} = \frac{0.061}{17.5} = 0.00348$$

(ii) (c) : p = Vapour pressure of solvent – lowering in vapour pressure = 17.5 – 0.061 = 17.439 mm of Hg

(iii) (a) : $\frac{p_A^\circ - p_A}{p_A^\circ} = x_B = 0.00348$

Hence, mole fraction of sugar = 0.00348

OR

(c) : $M_B = \dfrac{w_B M_A}{w_A\left(\dfrac{p_A^\circ - p_A}{p_A^\circ}\right)}$

$w_B = 5$ g, $M_A = 18$ g, $w_A = 108$ g

$$M_B = \frac{5 \times 18}{108 \times 0.00348} = 240$$

(iv) (b): $\dfrac{p_A^\circ - p_A}{p_A^\circ} = x_B = \dfrac{w_B \times M_A}{M_B \times w_A}$

$$\frac{17.5 - p_A}{17.5} = \frac{25 \times 18}{450 \times 180} = 5.56 \times 10^{-3}$$

$17.5 - p_A = 17.5 \times 5.56 \times 10^{-3}$
$17.5 - p_A = 0.0973$
$p = 17.40$ mm Hg

5. **(i) (b) :** $m = \dfrac{0.052}{180} \times \dfrac{1000}{80.2} = 0.0036$

(ii) (c) : $\Delta T_b = K_b \times m = 5.2 \times 0.0036 = 0.0187$ K
$T_b = 373 + 0.0187 = 373.0187 \text{ K} \approx 373.02$ K

(iii) (d): $\Delta T_f = K_f \times m = 1.86 \times 0.0036 = 0.067$ K

(iv) (a) : Moles of glucose $= \dfrac{0.052}{180} = 0.00028$

Moles of water $= \dfrac{80.2}{18} = 4.455$

Mole fraction of glucose $= \dfrac{0.00028}{4.45 + 0.00028} = 6.28 \times 10^{-5}$

OR

(c) : Depression in freezing point or elevation in boiling point is proportional to molarity which is proportional to number of moles. For same amount, higher the molar mass of solute lower will be number of moles. Hence, lower will be the colligative property.

6. **(i) (b):** $K_H = 4.27 \times 10^5$ mm Hg
$p = 760$ mm Hg
According to Henry's law, $p = K_H \times x_{CH_4}$

$$x_{CH_4} = \frac{p}{K_H} = \frac{760}{4.27 \times 10^5} = 1.78 \times 10^{-3}$$

(ii) (a) : According to Henry's law, $m = K_H \times p$
$6.56 \times 10^{-2} = K_H \times 1$
$K_H = 6.56 \times 10^{-2}$
For another case, $5 \times 10^{-2} = 6.56 \times 10^{-2} \times p$

$$p = \frac{5 \times 10^{-2}}{6.56 \times 10^{-2}} = 0.762 \text{ bar}$$

(iii) (c) : Higher the value of K_H at a given pressure, the lower is the solubility of the gas.

(iv) (c) : The mole fraction of the gas in solution

$$x = \frac{p}{K_H} = \frac{1}{150 \times 10^3}$$

If n is the number of moles of gas in a solution of 1 L of water containing 55.5 mol then

$$x = \frac{n}{n + 55.5} \text{ or, } \frac{n}{55.5} = \frac{1}{150 \times 10^3}$$

[$n + 55.5 \approx 55.5$, as n is very small]

$$n = \frac{55.5}{150} \times 10^{-3} = 0.37 \text{ millimoles}$$

OR

(a)

7. **(i) (b):** Depression in freezing point is a colligative property which depends on the number of particles present in the solution. As both 0.1 M solution of glucose and 0.1 M solution of urea contain same number of moles (number of particles) therefore, both will have same depression in freezing point.

OR

(c) : Density of water is maximum at 4°C *i.e.*, 277 K.

(ii) (a)

(iii) (a) : Freezing point of a substance is defined as the temperature at which the vapour pressure of its liquid is equal to the vapour pressure of the corresponding solid. Since the addition of a non-volatile solute always lowers the vapour pressure of solvent, therefore it will be in equilibrium with solid phase at a lower pressure and hence at a lower temperature.

(iv) (d): Elevation in boiling point (ΔT_b) = $K_b \times m$
Depression in freezing point (ΔT_f) = $K_f \times m$
Elevation in boiling point and depression in freezing point are colligative properties *i.e.*, they depend only on the number of particles of the solute. Value of K_b and K_f are different, so ΔT_b and ΔT_f are also different.

8. (i) (a)

(ii) (a)

(iii) (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.

OR

(b)

(iv) (d) : For ideal solution, $\Delta H_{\text{mix}} = 0, \Delta V_{\text{mix}} = 0$

9. (i) (c) : If the red blood cells are placed in pure water, pressure inside the cells increases as the water is drawn in and the cell swells.

OR

(a) : (i) Osmotic pressure of urea
$w_B = 3.4$ g, $V = 200$ mL $= 0.2$ L, $T = 293$ K
$M_B = 60$, $R = 0.083$ L bar mol^{-1} K^{-1}

$$\pi = \frac{w_B RT}{M_B V} = \frac{3.4 \times 0.083 \times 293}{60 \times 0.2} = 6.89 \text{ bar}$$

(ii) Osmotic pressure of cane sugar

$$\pi = \frac{W_B RT}{M_B V} = \frac{1.6 \times 0.083 \times 293}{342 \times 0.2} = 0.57 \text{ bar}$$

$\pi = 6.89 + 0.57 = 7.46$ bar

(ii) (b)

(iii) (c) : Osmotic pressure is a colligative property.

(iv) (a)

10. (i) (c) : In pressure cooker, water boils above 100°C. When the lid of cooker is opened, pressure is lowered so that boiling point decreases and water boils again.

(ii) (a): $M_B = \dfrac{K_b \times 1000 \times W_B}{\Delta T_b \times W_A}$

$K_b = 2.53$ K kg mol^{-1}, $W_B = 3.24$ g,
$\Delta T_b = 0.81$ K, $W_A = 40$ g

$$M_B = \frac{2.53 \times 1000 \times 3.24}{0.81 \times 40} = 253$$

Let molecular formula of sulphur = S_x
$x \times 32 = 253$ or $x = 7.91 \approx 8$

(iii) (a)

(iv) (a)

OR

(c) : Elevation in boiling point of two isotonic solutions is the same and elevation in boiling point depends upon the concentration of solute not on the boiling point.

11. (b): A homogeneous mixture consists of a single phase which has properties that may differ from those of the individual components *i.e.*, solute and solvent.

12. (b): In amalgam, solute and solvent are uniformly distributed.

13. (a): Molecular weight of urea (NH_2CONH_2)
$= 14 + 2 + 12 + 16 + 14 + 2 = 60$

$$\text{Number of moles} = \frac{\text{Weight}}{\text{Molecular weight}} = \frac{60}{60} = 1$$

$$m = \frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}} = \frac{1 \text{ mol}}{1 \text{ kg}} = 1 \text{m}$$

14. (b): Molality does not depend upon volume thus, it does not depend on temperature.

15. (c) : Benzene and toluene do not form H-bonding with each other.

16. (c) : The vapour pressure of solution is found to be lower than the vapour pressure of pure solvent. In the solution, the surface has both solute and solvent molecules, thereby the number of solvent molecules gets reduced at the surface, consequently, the number of solvent molecules escaping from the surface is correspondingly reduced and this results in the decrease in vapour pressure of the solvent.

17. (a): According to colligative property, on addition of a non-volatile solute to a volatile solvent, the freezing point of solution decreases.

18. (a): On mixing two dissimilar substances, their molecular environment changes. Suppose the two components that are mixed to form a non-ideal solution are *A* and *B*.
When $A - B$ interactions $<$ $A - A$ or $B - B$ interactions, there is a positive deviation from Raoult's law.
When $A - B$ interaction $>$ $A - A$ or $B - B$ interactions, there is a negative deviation from Raoult's law.

19. **(b):** On adding a non-volatile solute in a liquid, the vapour pressure decreases because some molecules of the solvent on the surface are replaced by the molecules of the solute.

20. **(a):** A colligative property of a solution is one that depends only on the number of particles of the solute dissolved in it, rather than on the nature of the solute.

21. **(c):** At 373 K (100°C), the vapour pressure of water is equal to 1 atmospheric pressure which is 1.013 bar.

22. **(c):** Both the solute and solvent will form the vapours but vapour phase will become richer with the more volatile component.

23. **(b):** Osmosis is a phenomenon in which the solvent flows from a solution of lower concentration to the solution of higher concentration.
Here, movement of water molecules takes place in highly concentrated salt content of blood cell to such an extent that the cell membrane ruptures.

24. **(c):** Sodium ion, Na^+ and potassium ion, K^+ are responsible for maintaining proper osmotic pressure balance inside and outside of the cells of organisms.

25. **(d):** The freezing point keeps on becoming lower and lower. Depression in freezing point is a colligative property as it depends on the number of particles of the solute present in solution, so solution will freeze more rapidly on adding large amount of non-volatile solute.

26. **(b):** Moles of solute are equal to product of molarity and volume (*i.e.*, $\text{Mol L}^{-1} \times \text{L} = \text{Mol}$) and when we add more solvent, the volume increases but the molarity decreases correspondingly so that their product *i.e.*, the total number of moles remains constant.

27. **(a)**

28. **(c):** Elevation in boiling point and depression in freezing point are colligative properties because they depend only on the number of solute particles in a solution irrespective of their nature. But all colligative properties are not used for mass determination for every substance, as some give very low precision, or require excessive heating or cooling.

29. **(a):** If a pressure larger than the osmotic pressure is applied to the solution side, the pure solvent flows out of the solution to the solvent through semi-permeable membrane and this phenomenon is called reverse osmosis.

30. **(c):** Camphor has high molal depression constant.