

EXAM
DRILL

Solution

ANSWERS

1. (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_A = 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

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

$w_B = 5 \text{ g}$, $M_A = 18 \text{ g}$, $w_A = 108 \text{ g}$

$$M_B = \frac{5 \times 18}{108 \times 0.00348} = 239.46 \approx 240$$

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

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

$$17.5 - p_A = 17.5 \times 5.56 \times 10^{-3}$$

$$17.5 - p_A = 0.0973$$

$$p = 17.40 \text{ mm Hg}$$

2. (d) : Partial vapour pressure of a component in a solution cannot be obtained without knowing the number of moles of both solvent and solute present in solution.

3. (d) : Henry's law constant is in the unit of pressure, hence we use relation $p = K_H \times x_{N_2}$

$$x_{N_2} = \frac{p}{K_H} = \frac{0.840 \text{ bar}}{82.35 \times 10^3 \text{ bar}}$$

$$= 1.0 \times 10^{-5} \text{ L}$$

1000 mL H_2O = 1000 g H_2O ($d = 1 \text{ g mL}^{-3}$)

$$\therefore \text{Moles of } \text{H}_2\text{O} = \frac{1000}{18} = 55.5 \text{ moles}$$

Let the number of moles of nitrogen be n .

$$\text{Then } x_{N_2} = \frac{n}{n+55.5} \approx \frac{n}{55.5} \text{ (since, } n \text{ is very small)}$$

$$\therefore n = 55.5 \times 1.0 \times 10^{-5}$$

$$= 5.55 \times 10^{-4} \text{ mol} = 5.55 \times 10^{-4} \times 1000 \text{ mmol}$$

$$= 5.55 \times 10^{-1} \text{ millimole} = 0.555 \text{ millimole}$$

4. (d) : Water-alcohol solution

OR

(d)

$$5. (d) : 2 = \frac{\text{Mass}}{63} \times \frac{1000}{250}$$

$$\text{Mass} = \frac{63}{2} \text{ g}$$

$$\text{Mass of acid} \times \frac{70}{100} = \frac{63}{2}$$

Mass of acid = 45 g

6. (c) : 0.1 M AgNO_3 and 0.1 M NaCl are mixed together.

\Rightarrow 0.1 M AgNO_3 solution contains 0.1 moles of Ag^+ and 0.1 moles of NO_3^- in 1000 mL solution.

\Rightarrow 0.1 M NaCl solution contains 0.1 moles of Na^+ and 0.1 moles of Cl^- ions in 1000 mL solution.

\therefore Total moles of $\text{NO}_3^- = 0.1$, Total vol. of solution = 2000 mL

$$\therefore \text{Molarity of } \text{NO}_3^- \text{ ions} = \frac{0.1 \text{ mol}}{2 \text{ L}} = 0.05 \text{ M}$$

7. Shriveled

8. Mole fraction

9. 5 and 3 respectively

10. $M = P \times d \times 10 / \text{Molecular mass}$

11. (b)

12. (b)

13. (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.

14. (a)

15. (a)

16. (i) Positive deviation. The temperature will decrease.

(ii) When we apply pressure on solution side more than osmotic pressure, osmosis can be reversed. It is used for desalination of sea water.

17. Molarity : It is the number of moles of solute dissolved per litre of the solution.

$$M = \frac{w_B \times 1000}{M_B \times V_{(\text{sol.})}}$$

On increasing the temperature, molarity of solution decreases because on increasing temperature, volume of solution increases.

$$18. \frac{p^\circ - p_s}{p^\circ} = x_2 \quad \therefore \frac{p^\circ - p_s}{0.80} = 0.25$$

$$\text{or } p^\circ - p_s = 0.20 \text{ atm}$$

19. If the pressure is higher than the osmotic pressure is applied on the solution, the solvent will flow from the solution into the pure solvent through the semipermeable membrane. This process is known as reverse osmosis.

20. Osmotic pressure is the pressure required to stop the flow of water. The osmotic pressure is highest where the water concentration is lowest. That's why water moves toward higher areas of osmotic pressure. The osmotic pressure is greatest where the solute concentration is highest, and the water concentration is lowest.

21. The vapour pressure of the volatile components is given by Raoult's law *i.e.*, $p = p^\circ x$. In solution of gas in liquid it is given by Henry's law *i.e.*, $p = K_H x$.

On comparing the both we can say that partial pressure of volatile liquid (Raoult's law) or gas (Henry's law) is directly proportional to its mole fraction.

The only difference is the proportionality constant K_H and p° . If one of the component is so volatile that it can exist as a gas then Raoult's law become a special case of Henry's law where $p^\circ = K_H$.

22. Temperature: Generally, solubility increases with temperature in case of solvents. Gases become less soluble in with increase in temperature.

Polarity: In most cases solute dissolves in a solvent that have a similar polarity.

Pressure: For solid and liquid solutes, pressure does not affect solubility.

Molecular size: Smaller particles dissolve faster.

OR

$$W_2 = 1.00 \text{ g}, W_1 = 50 \text{ g}, K_f = 5.12 \text{ K kg mol}^{-1}, \Delta T_f = 0.40 \text{ K}$$

$$\Delta T_f = \frac{K_f \times W_2 \times 1000}{M_2 \times W_1}$$

$$M_2 = \frac{K_f \times W_2 \times 1000}{W_1 \times \Delta T_f} = \frac{5.12 \times 1 \times 1000}{50 \times 0.40} \\ = 256 \text{ g mol}^{-1}$$

23. Calculated molecular mass of AB = 58.2

Observed molecular mass of AB = 30

$$\text{van't Hoff factor } i = \frac{\text{Calculated molecular mass}}{\text{Observed molecular mass}}$$

$$i = \frac{58.2}{30} = 1.94$$

$$\text{Degree of dissociation } (\alpha) = \frac{i-1}{n-1}$$

Substance AB on dissociation gives 2 mol of substance A and B. Hence, $n = 2$, $i = 1.94$

$$\alpha = \frac{1.94-1}{2-1} = \frac{0.94}{1} \Rightarrow \alpha = 0.94$$

OR

$$\frac{p_1^0 - p_1}{p_1^0} = \frac{n_2}{n_1}$$

Now 4% w/w urea solution means 4 gram urea in 96 gram water and $p_1^0 = 0.025 \text{ bar}$

$$\therefore n_1 = \frac{w_1}{M_1} = \frac{96}{18} = 5.33 \text{ mole of water}$$

$$n_2 = \frac{w_2}{M_2} = \frac{4}{60} = 0.0667 \text{ mole of water}$$

Now putting these values of p_1^0 , n_1 and n_2 in Raoult's law

$$\text{equation, } \frac{0.025 - p_1}{0.025} = \frac{0.0667}{5.33}$$

$$\therefore 0.025 - p_1 = \frac{0.0667 \times 0.025}{5.33} = 0.000313$$

$$\therefore p_1 = 0.025 - 0.000313 = 0.02469 \text{ bar}$$

The vapour pressure of 4% w/w aqueous solution of urea will be 0.02469 bar.

24. (a) (i) Molal boiling point elevation constant : Molal elevation constant can be defined as "the elevation in boiling point of the solution in which 1 gm of solute is dissolved in 1000 g of solvent".

\therefore Elevation in boiling point:

$$\Delta T_b \propto m$$

$$\Delta T_b = K_b m$$

$$m = 1, \Delta T_b = K_b$$

where K_b = Molal boiling point elevation constant.

(ii) Molal freezing point depression constant : Molal depression constant may be defined as "the depression in freezing point for 1 molal solution *i.e.*, solution in which 1 mole of solute is dissolved in 1000 g of solvent."

\therefore Depression in freezing point:

$$\Delta T_f \propto m$$

$$\Delta T_f = K_f$$

If $m = 1$, $\Delta T_f = K_f$

Where K_f = Molal freezing point depression constant.

(b) The two ways by which vapour pressure can be lowered are

- (1) by decreasing the temperature
- (2) by adding a non-volatile substance.

25. (i) Mole fraction : It is denoted by x and subscript used on the right-hand side of x denotes the component. It is defined as number of moles of the component divided by total number of moles of all the components.

Mole fraction unit is very useful in relating some physical properties of solutions, say vapour pressure with the concentration of the solution and quite useful in describing the calculations involving gas mixtures.

(ii) Isotonic solutions : Two solutions having the same osmotic pressure at a given temperature. When such solutions are separated by semipermeable membrane no osmosis occur between them.

For example, the osmotic pressure associated with the fluid inside the blood cell is equivalent to that of 0.9% (mass/volume) sodium chloride solution, called normal saline solution and it is safe to inject intravenously.

(iii) Hypertonic solution : A solution with higher osmotic pressure than another solution. If we place the cells in a solution containing more than 0.9% (mass/volume) sodium chloride, water will flow out of the cells and they would shrink.

26. Given, $T_f = 271.9$ K

$w = 1.25$ g, $W = 20$ g, $K_f = 1.86$

$\Delta T_f = T_f^\circ - T_f = 273 - 271.9$

$\Delta T_f = 1.1$

$\Delta T_f = K_f \times \text{molality}$

$$\Delta T_f = \frac{w}{m \times W} \times 1000 \times K_f$$

$$m = \frac{w \times 1000 \times K_f}{\Delta T_f \times W}$$

$$\Rightarrow m = \frac{1.25 \times 1000 \times 1.86}{1.1 \times 20}$$

$$\Rightarrow m = 105.68 \text{ g mol}^{-1}$$

27. $W_2 = 2.56$ g, $W_1 = 100$ g, $\Delta T_f = 0.383$ K

$K_f = 3.83$ K kg mol⁻¹, $\Delta T_f = K_f \times m$

$$\Rightarrow \Delta T_f = K_f \times \frac{W_2}{M_2} \times \frac{1000}{W_1}$$

$$\Rightarrow M_2 = \frac{W_2 \times 1000}{\Delta T_f \times W_1} \times K_f$$

$$= \frac{2.56 \times 1000}{0.383 \times 100} \times 3.83 = 256 \text{ g mol}^{-1}$$

$$\therefore i = \frac{\text{Normal atomic mass}}{\text{Observed atomic mass}} = \frac{32}{256} = \frac{1}{8}$$

Sulphur exists as S₈.

28. (a) i for 1 M NaCl = 2

i for sugar solution = 1

$$\therefore \Delta T_b = iK_b m = 2K_b \text{ (for NaCl)}$$

$$\Delta T_b = K_b \text{ (for sugar)}$$

$\therefore \Delta T_b$ of 1 M NaCl solution is double than that of 1 M sugar solution.

(b) $W_2 = 6.21$ g, $W_1 = 24.0$ g

$T_b = 68.04$ °C, $T_b^\circ = 61.7$ °C and $K_b = 3.63$ °C/m

$$\Delta T_b = T_b - T_b^\circ = 68.04 \text{ °C} - 61.7 \text{ °C} = 6.34 \text{ °C}$$

$$\Delta T_b = \frac{K_b \times W_2 \times 1000}{M_2 \times W_1} \text{ or } M_2 = \frac{K_b \times W_2 \times 1000}{\Delta T_b \times W_1}$$

$$M_2 = \frac{3.63 \text{ °C m}^{-1} \times 6.21 \text{ g} \times 1000}{6.34 \text{ °C} \times 24.0 \text{ g}} = 148.15 \text{ g mol}^{-1}$$

29. (a) When a non-volatile solute is added to a solvent, the vapour pressure of the solvent (above the resulting solution) is lower than the vapour pressure above the pure solvent.

(b) The elevation in boiling point of a solution is a colligative property which depends on the number of moles of solute added. Higher the concentration of solute added, higher will be the elevation in boiling point. Thus, 2 M glucose has higher boiling point than 1 M glucose solution.

(c) Liquid A with lower boiling point is more volatile, hence it will have higher vapour pressure.

30. (a) (i) As KCl is an electrolyte and one formula unit of KCl dissociates to give two ions (K⁺ and Cl⁻), therefore molar concentration of particles in the solution = $0.1 \times 2 \text{ M} = 0.2 \text{ M}$. As elevation of boiling point (or any colligative property) is directly proportional to number of particles in solution, hence 0.1 M KCl has higher boiling point than 0.1 M glucose.

(ii) Salting is used because most bacteria, fungi and other potentially pathogenic organism cannot survive in a highly salty environment, due to the hypertonic nature of salt. Any living cell in such an environment will become dehydrated through osmosis and die or become temporarily deactivated.

(b) (i) Osmotic pressure can be measured at room temperature and molarity of the solution is used instead of molality.

(ii) Its magnitude is large as compared to other colligative properties even for very dilute solutions.

OR

Given : $T_f = 272.4$ K, $T_f^\circ = 273.0$ K

$K_f = 1.86$ K kg mol⁻¹, $K_b = 0.512$ K kg mol⁻¹

$P^\circ = 23.756$ mm Hg

(i) $\Delta T_f = K_f m$

or, $273.0 \text{ K} - 272.4 \text{ K} = 1.86 \text{ K kg mol}^{-1} \times m$

$$\text{or, } m = \frac{0.6 \text{ K}}{1.86 \text{ K kg mol}^{-1}} = 0.3225 \text{ mol kg}^{-1}$$

$$\begin{aligned} \text{(ii) } \Delta T_b &= K_b \cdot m \\ &= 0.512 \text{ K kg mol}^{-1} \times 0.3225 \text{ mol kg}^{-1} \\ &= 0.16512 \text{ K} \end{aligned}$$

$$\text{Again, } \Delta T_b = T_b - T_b^\circ$$

$$\begin{aligned} \text{or, } T_b &= T_b^\circ + \Delta T_b \\ &= 373 \text{ K} + 0.16512 \text{ K} = 373.16512 \text{ K} \end{aligned}$$

$$\text{(iii) Using Raoult's law, } x_2 = \frac{m}{m + \frac{1000}{18}}$$

$$x_2 = \frac{0.3225 \text{ mol kg}^{-1}}{0.3225 + 55 \text{ mol kg}^{-1}} = 0.0058$$

$$\frac{\Delta P}{P^\circ} = x_2 \Rightarrow \frac{\Delta P}{23.756} = 0.0058$$

$$\text{or, } \Delta P = 0.0058 \times 23.756 = 0.137 \text{ mm}$$

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