: Bhubaneswar Region

CHAPTER 2-SOLUTIONS

1 MARK QUESTIONS

1 What is molarity?
2 What do you understand by saying that molality of a solution is 0.2?
3 Why is the vapour pressure of a liquid remains constant at constant temperature?
4 Define Azeotropes?
5 Which substance is usually added into water in the car radiator to act as antifreeze?
6 Which liquids form ideal solution?
7 Which property of solution depend only upon the number of moles of solute dissolved and not on the nature of the solute?
8 Write one example each of solid in gas and liquid in gas solution?
9 What is molal elevation constant or ebullioscopic constant?
10 Define van't Hoff factor.
11 Two liquids A and B boil at 120 C and 160 C respectively. Which of them has higher vapour pressure at 70 C?
12 What happens when blood cells are placed in pure water?
13 What is the effect of temperature on the molality of a solution?
14 Write Henry's law.
15 What is an antifreeze?
16 Why cutting onions taken from the fridge is more comfortable than cutting onions lying at room temperature?
17 What will be the van't Hoff factor for O.1 M ideal solution?
18 What is the optimum concentration of fluoride ions for cleaning of tooth?
19 What role does the molecular interaction play in the solution of alcohol and water?
20 Henry law constant for two gases are 21.5 and 49.5 atm, which gas is more soluble .

ANSWER KEY FOR 1 MARK

1 The number of moles of solute dissolved in one litre or 1dm3 of solution is known as molarity.
2 This means that 0.2 mol of the solute is dissolved in 1Kg of the solvent
3 At equilibrium, the rate of evaporation = rate of condensation. Hence the vapour pressure of a liquid is constant at constant temperature.

4 Constant boiling mixtures are called Azeotropes
5 Ethylene glycol is usually added into water in the car radiator to act as antifreeze.
6 Liquids having similar structure and polarities
7 Colligative properties.
8 Solid in gas e.g. Camphor in nitrogen gas. Liquid in gas – e.g. Chloroform mixed with N2 gas
9 The elevation in boiling point which takes place when molality of the solution is unity, is known as ebullioscopic or molal elevation constant.
10 The ratio of the observed colligative property to the theoretical value is called van't Hoff factor.
11 Lower the boiling point, more volatile it is .So liquid A will have higher vapour pressure at 70 ^oC.
12 Water molecules move into blood cells through the cell walls. So, blood cells swell and may even burst.
13 No effect.
14 The solubility of a gas in a liquid is directly proportional to the partial pressure of the gas at a given temperature.
15 An antifreeze is a substance which is added to water to lower its freezing point. e.g. Ethylene glycol
16 The vapour pressure is low at lower temperature. So, less vapours of tear – producing chemicals are produced
17 Van't Hoff factor = 1, because ideal solution does not undergo dissociation or association.
18 The optimum concentration of fluoride ions for the cleaning of tooth is 1.5 ppm. [If it is more than 1.5 ppm it can be poisonous and if less than 1.5 ppm it ineffective.]
19 Positive deviation from ideal behavior.
20 KH is inversely proportional to solubility

SHORT ANSWER TYPE QUESTIONS OF 2 MARK

1 State Raoult's law. Prove that it is a special case of Henry' law?
2 List two conditions that ideal solutions must satisfy.
3 Explain ideal and non-ideal solutions with respect to intermolecular interactions in a binary solution of A and B.
4
  a. What are minimum boiling and maximum boiling azeotropes?
  b. Can azeotropes be separated by fractional distillation?
5
  a. When a non-volatile solute is added to solvent,there is increase in boiling point of solution.Explain.
  b. Define ebullioscopic constant and give its units.
6 How did Van't Hoff explain the abnormal molecular masses of electrolytes like KCl in water and non-electrolytes like benzoic acid in benzene.
7 When a pressure higher than the osmotic pressure is applied on the surface of the solution separated from a solvent by semi permeable membrane, what will happen?
8 The freezing depression of 0.1M sodium chloride solution is nearly twice that of 0.1 M glucose solution. Explain?
9 The depression in freezing point is a colligative property. Explain.
10 Equimolar solution of glucose and Common salt are not isotonic. Why?

Answer key

1 Raoult's law states that partial pressure of a volatile component of a solution is directly proportional to its mole fraction. It is a special case of Henry' law because it becomes the same when "Kh" (Henry constant) is equal to pressure of pure solvent.

2

a. ΔH_{mixing} and ΔV_{mixing} of ideal solutions should be zero.

b. They should obey Raoult's law over the entire range of concentration.

3 For the given binary solution of A and B, it would be ideal if A-B interactions are equal to A-A and B-B interactions and it would be non-ideal if they are different to each other.The deviation from ideal behavior will be positive if A-B interactions are weaker as compared to A-A and B-B. The deviation will be negative if A-B interactions are stronger as compared to A-A and B-B.

4 (i) Minimum boiling azeotropes are the non-ideal solutions showing positive deviation while maximum boiling azeotropes are those which show negative deviation. Because of positive deviation their vapour pressures are comparatively higher and so they boil at lower temperatures while in case of negative deviation, thevapour pressures are lesser and so higher temperature are required for boiling them.(ii) No, azeotropes can't be separated by fractional distillation

5 (i) When a non-volatile solute is added to a volatile solvent the vapour pressure of pure solvent decreases because a part of the surfaceis occupied by non-volatile solute which can't volatilise. As a result, thevapour pressure of solution decreases andhence, the solution requires a comparatively higher temperature to boil causing an elevation of boiling point. (ii) Ebullioscopic constant is defined as the elevation in boiling point of a solution of a non-volatile solute when its molality is unity. Its units are K Kg mol^{-1}

6 The molecular mass of KCl in aqueous medium has been observed to be almost half than expected and it has been explained as dissociation of KCl into K^+ ions and Cl^- ions when actual no. of particles become double and so become the colligative properties but since molecular mass is always inversely proportional to colligative property it becomes almost half.In case of benzoic acid in benzene, association of molecules take place when they dimerise and their no. becomes almost half and so molecular mass doubles as a result.

7 Reverse osmosis will take place. We will observe the movement of solvent molecules from the solution to solvent phase and the level of solution will decrease.

8 Sodium chloride being ionic compound ionizes as ($NaCl \rightarrow Na^+ + Cl^-$) in aqueous solution. The concentration of solute particles in this case becomes approximately 0.2 M which is twice the concentration of glucose solution. Consequently, freezing point depression of NaCl solution is also approximately twice that of glucose solution.

9 The freezing point depression depends upon the molal concentration of the solute and does not depend upon the nature of the solute .It is therefore, a colligative property

10 Glucose is a non electrolyte, when added to water it do not break up into ions whereas Common salt is an electrolyte when added to water it breaks up to give Sodium and chloride ions , The number of particles in solution of Common salt are nearly double the number of particles in the solution of glucose so the osmotic pressure of common salt solution is nearly twice that if Glucose solution.

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It is a special case of Henry' law because it becomes the same when "Kh" (Henry constant) is equal to pressure of pure solvent.

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QUESTIONS FOR 3 MARK

1. A 5% solution of sucrose $C_{12}H_{22}O_{11}$ is isotonic with 3% solution of an unknown organic substance. Calculate the molecular mass of unknown substance.
2. A solution of Barium Chloride is prepared by dissolving 3.100 g of it in 250 g of water. The solution boils at 100.083^oC. Calculate the Van't Hoff factor and Molality of this solution.(Kb for water = 0.52 Km-1, Molar mass of BaCl2 = 208.3 g mol-1)
3. Why semi permeable membrane is so important in the phenomenon of osmosis? What are isotonic, hypo tonic and hyper tonic solutions? Does osmosis take place in all three types of solutions?
4. Which will have more osmotic pressure and why? Solution prepared by dissolving 6g/L of CH_3COOH orSolution prepared by dissolving 7.45g/L of KCl
5. What is Bends ? If a diver had the "bends", describe how this can be treated.
6. At 300 K. 18g of glucose present per litre its solution has an osmotic pressure of 4.98 bars .If the osmotic pressure of solution is 1.52 bars on the same temperature, what would be its concentration?
7. The freezing depression of 0.1M sodium chloride solution is nearly twice that of 0.1 M glucose solution.
8. Calculate the amount of NaCl must be added to 1000 ml of water so as to reduce its freezing point by two Kelvin. For water K_f = 1.86 K Kg mol^{-1} , give that the density of water is 1.0 g ml^{-1} and NaCl is completely dissociated.
9. Predict the Boiling point of solution prepared by dissolving 25.0g of urea and 25.0 g of thiourea in 100 gram of water. Given for water K_b= 0.52 K Kg mol^{-1} and Boiling point of pure water is 373.15 K.
10. Predict the Boiling point of solution prepared by dissolving 3.42g of sugarcane in 100 gram of water. Given for water K_b= 0.52 K Kg $mol^{-1}$and Boiling point of pure water is 373.15 K.Ans.

ANSWER KEY FOR 3 MARK

Ans.1

$$\pi_1 = \pi_2$$
$$C_1RT = C_2RT$$
$$\frac{n_1}{V} = \frac{n_2}{V}$$
$$\Rightarrow \frac{W_1}{m_1} = \frac{W_2}{m_2}$$
$$\Rightarrow \frac{5}{342} = \frac{3}{m_2}$$
$$\therefore m_2 = \frac{3 \times 342}{5}$$
$$= 205.2$$

Ans.2 Observed Tb = 100.083 - 100 =0.083 0C

$$\text{Molality of the solution} = \frac{w_{solute} \times 1000}{M_{solute} \times W_{solvent}}$$
$$M_{solute} = \frac{3.1 \times 1000}{208.3 \times 250} = 0.0595$$
$$\Delta T_b = K_b \times m = 0.05952 \times 0.52$$
$$= 0.03095$$
$$i = \frac{\text{obs.}\,\Delta T_b}{\text{Normal}\,\Delta T_b} = \frac{0.083}{0.03095} = 2.68$$

Ans.3 The semi permeable membrane is very importantin the phenomenon of osmosis because they only permit the movement of solvent molecules through them.
Two solutions having similar osmotic pressure at a given temperature are called isotonic solutions. If the given solution has less osmotic pressure it is called hypo tonic and it is hyper tonic if its osmotic pressure is higher than the the solution on the other side of semi permeable membrane. Osmosis takes place only in hypo tonic and hypertonic solutions.

Ans.4

$$\text{Moles of } CH_3COOH = \frac{\text{Mass}}{\text{Mol. Wt.}} = \frac{6}{60} = 0.1$$
$$\text{Moles of KCl} = \frac{\text{Mass}}{\text{Mol. Wt.}} = \frac{7.45}{74.5} = 0.1$$

Molar concentration of both the solutions is same.

KCl ionizes into K^+ and Cl^- where as CH_3COOH does not ionize

Osmotic pressure is colligative property

Its value depend on number of particles.

Since, KCl produces more ions so, osmotic pressure of KCl will be more than that of CH3COOH.

Ans.5 Scuba divers cylinder has a mixture of helium, nitrogen and oxygen ,as they go down at high pressure which increases the solubility of these gases in the blood when they come up pressure decreases and nitrogen is released as the solubility decreases and the bubbles of nitrogen gas can block capillaries causing condition called bends which is both painful and dangerous. In order to avoid formation of bends in blood the divers are subjected to decompression chambers where pressure is lowered down gradually releasing the gas from blood slowly.

Ans6. For solution A V= n RT
4.98 x 1L = 18/180 x R x T
For solution B V= n RT
1.52 x 1L = n x R x T
1.52 x 1L/ n = 4.98 x 1L / 0.1
1.52 / n = 4.98 / 0.1
n = 1.52 x 0.1 / 4.98 = 0.035moles
c= 0.035 mol L^{-1}

Ans7. Sodium chloride being ionic compound ionizes as (NaCl $\rightarrow$ Na^++ Cl^-) in aqueous solution. The concentration of solute particles in this case becomes approximately 0.2 M which is twice the concentration of glucose solution. Consequently, freezing point depression of NaCl solution is also approximately twice that of glucose solution.

Ans.8 Mass of water = density x volume= 1 x 1000 = 1000g = 1Kg.
$\Delta T_f = i\ K_f\ m$
2 = (2 x 1.86 x z / 58.5 x 1000) x 100
z = 58.5/1.86= 31.45g

ans.9 No of moles of urea= mass of urea / molar mass of urea.
= 25/ 60 =0.42
No of moles of thiourea= mass of thiourea / molar mass of thiourea.
= 25/76 = 0.33
molality of solution= moles of solute / mass of solvent in Kg
molality of solution= (moles of solute / mass of solvent in g) x 1000
molality of solution= (0.33+0.42/ 100) x 1000
molality of solution= 1.50m
ΔT_b =0.52 x 1.50= 5.44K
T_b (solution) - T_b (solvent) = 5.44K
T_b (solution) = 5.44K + 373.15 =378.59K
Ans.10.$\Delta T_b = K_b \times m$
ΔT_b = (0.52 x 3.42g/342g mol^{-1} x 100 } x 1000
ΔT_b = 0.052 x100 /1000 = 0.0052 K
T_b (solution) - T_b (solvent) = 0.0052K
T_b (solution) = 0.0052K + 373.15= 373.1552K

QUESTIONS FOR 5 MARK SOLUTION

Q1 (a) Difference between molarity and molality for a solution. How does a change in temperature influence their values?

(b) Calculate the freezing point of an aqueous solution containing

10.50 g of $MgBr_2$ in 200 g of water. (Molar mass of $MgBr_2$ =184 g) (K_f for water = 1.86 K kg mol^{-1})

OR

(a) Define the terms osmosis and pressure. Is the osmotic pressure of a solution a colligative property? Explain.

(b) Calculate the boiling point of a solution prepared by adding 15.00 g of NaCl to 250.0 g of water.(K_b for water = 0.512 K kg mol^{-1}), Molar mass of NaCl = 58.44 g.

Q.2

A 1.00 molal aqueous solution of trichloroacetic acid (CCl_3COOH) is heated to its boiling point. The solution has the boiling point of 100.18 °C. Determine the van't Hoff factor for trichloroacetic acid. (K_b for water = 0.512 K kg mol^{1})

OR

Define the following terms:

(i) Mole fraction

(ii) Isotonic solutions

(iii) Van't Hoff factor

(iv) Ideal solution

Q.3 A solution is prepared by dissolving 30g of non-volatile non-electrolyte solute in 90g water. The vapour pressure of solution was 2.8 K Pa at 298K. When 18g of water was further added to it, the vapour pressure became 2.9 k Pa at 298K. Calculate molar mass of solute.

Q4 Question 1

a. Define the following terms:

i. Mole fraction

ii. Van't Hoff factor

b. 100 mg of a protein is dissolved in enough water to make 10.0 mL of a solution. If this solution has an osmotic pressure of 13.3 mmHg at 25° C, what is the molar mass of protein? (R=0.0821 L atm mol^{-1} K^{-1}and 760 mmHg = 1 atm)

or

a. What is meant by:

i. Colligative properties

ii. Molality of a solution

b. What concentration of nitrogen should be present in a glass of water at room temperature? Assume a temperature of 25°C, a total pressure of 1 atmosphere and mole fraction of nitrogen in air of 0.78.

[K_H for nitrogen = 8.42 x 10^{-7} M/mm Hg]Ans.

Q5(a) weak electrolyte AB is 5% dissociated in aqueous solution. What is the freezing point of a 0.100 molal aqueous solution of AB? For water K_f = 1.86 K

(b)0.02molal solution of acetic acid is 3% dissociated at 25^{o}C calculate the Osmotic pressure of the solution.Ans.

ANSWER FOR 5 MARKS

Ans 1

(a) Molarity is defined as the number of moles of solute dissolved per litre of solution.

(b) Mathematically $M = \frac{\text{Number of moles of solute}}{\text{Volume of solution in litres } (dm^3)}$

(c) Molality of a solution is defined as the number of moles of solute

(d) dissolved in 1000 grams of solvent.

(e) Mathematically, $m = \frac{\text{Number of moles of the solute}}{\text{Mass of solvent in kg}}$

(f) While molarity decreases with an increase in temperature, molality is independent of temperature. This happens because molality

(g) involves mass, which deos not change with a change in temperature, while molarity involves volume, which is temperature dependent.

(h) (b) Given w_2 = 10.50 g

(i) w_1 = 200g

(j) Molar mass of $MgBr_2$ (M_2) = 184 g

(k) Using the formula,

(l) $\Delta T_f = \frac{1000 \times k_f \times w_2}{w_1 \times M_2}$

(m) $= \frac{1000 \times 1.86 \times 10.50}{200 \times 184}$

(n) $= \frac{19.530}{200 \times 184} = 0.53$

(o) Now, $T_f = T_o - \Delta T_f$

(p) = 273 – 0.53 = 272.47 K

OR

(a) Osmosis : The process of flow of solvent molecules from pure solvent to solution or from solution of lower concentration of solution

(b) of higher concentration through a semi – permeable membrane is called osmosis.

(c) Osmotic pressure : The pressure required to just stop the flow of solvent due to osmosis is called osmotic pressure (□) of the solution.

(d) Yes, the osmotic pressure of a solution is colligative property. The osmotic pressure is expressed as.

(e) $\pi = \frac{n}{V} RT$

(f) Where, □ = osmotic pressure

(g) n = number of moles of solute

(h) V = volume of solution

(i) T = temperature

(j) From the equation, it is clear that osmotic pressure depends upon the number of moles of solute 'n' irrespective of the nature of the

(k) solute. Hence, osmotic pressure is a colligative property.

(l) (b) Given, $K_b = 0.512$ k kg mol^{-1}

(m) $w_2 = 15.00$ g

(n) $w_1 = 250.0$ g

(o) $M_2 = 58.44$ g

(p) Using the formula,

(q) $\Delta T_b = \frac{1000 \times K_b \times w_2}{w_1 \times M_2}$

(r) $= \frac{1000 \times 0.512 \times 15.00}{250.0 \times 58.44}$

(s) $= \frac{7.680}{14.600} = 0.52$

(t) Now, $T_b = T_o + \Delta T_b$

(u) = 373 + 0.53 = 373.53 K

$\Delta T = 100.18 - 100 = 0.18°C = 0.18\ K$

Now $i = \Delta T / K_b m$

$i = 0.18\ K / (0.512\ K\ kg\ mol^{-1})\ (1.00\ mol kg^{-1})$

$= 0.35$

Or

i. Mole fraction:
It is defined as the ratio of moles of a constituent to the total number of moles of the solution.

ii. Isotonic solutions:
Solutions which have the same osmotic pressure are called as isotonic solution.

iii. Van't Hoff factor:
It is the ratio of experimental values of a colligative property to the calculated value of the property when the solution behaves ideally

iv. Ideal solution:
A solution that obeys Raoult's law over all ranges of temperature and concentration and shows no internal energy change on mixing and no attractive force between components.

ANS.2

$p_A = p_A^o \chi_A$

Here, A = water

n = moles of solute

$$2.8 = p_A^o \frac{\frac{90}{18}}{\frac{90}{18} + n} \quad \text{.....................(i)}$$

$$2.9 = p_A^o \frac{\frac{90+18}{18}}{\frac{90+18}{18} + n} \quad \text{..........................(ii)}$$

On dividing equation (i) and (ii) we get

$$\frac{28}{29} = \frac{5(6+n)}{6(5+n)}$$

$$\therefore n = \frac{30}{23}$$

Thus,

Mass of solute = 30

ANS.3 Molecular mass = 23

ANS4(i) Mole fraction of a component is the ratio of number of moles of the component to the total number of moles of all the components.

(a) (ii) Van't Hoff factor is the ratio of normal molar mass to the abnormal molar mass.
(b) Van't Hoff factor is the ratio of observed value of colligative property to calculated value of colligative property assuming no association or dissociation.
(c) (b) Mass of protein = 100 mg = 0.1 g
(d) V= 10 Ml

$\pi = 13.3mm = \frac{13.3}{760} atm$

$\pi V = nRT$

$\left(no. of\ moles, n = \frac{0.1}{M}\right) 18594.008$

$\frac{13.3}{760} \times 0.01 = \frac{0.1}{M} \times 0.0821 \times 298$

$M = 13980\ g = 13.98 kg$

(e) Molar mass of protein = 13.98 kg

(f) **Or**

(g) (i) All the properties which depend on the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are known as colligative properties.

(h) (ii) Molality of solution is the number of moles of solute present in 1 kilogram of

$p_{N_2} = x_{N_2} \times P_{total}$

$= 0.78 \times 760 mmHg$

$= 592.8\ mmHg$

$K_H = 8.42 \times 10^{-7} M/mmHg$

$x_{N_2} = ?$

$x_{N_2} = K_H \times p_{N_2}$ [Since K_H is given in M/mmHg therefore this formula is being used]

$x_{N_2} = 8.42 \times 10^{-7} M/mmHg \times 592.8\ mmHg$

$x_{N_2} = 4991.376 \times 10^{-7}\ M$

$= 4.99 \times 10^{-4}\ M$

$n_{H_2O} = \frac{1000}{18} = 55.5 mol$

Since $n_{N_2} << n_{H_2O}$

$x_{N_2} \simeq \frac{n_{N_2}}{n_{H_2O}}$

$n_{N_2} = 4.99 \times 10^{-4} \times 55.5 = 276.9 \times 10^{-4} M$

solvent.(b)

Ans..5 (a) AB $\rightarrow$ B^- + A^+

1 0 0

1-α α α

α = 5/100 = 0.05

concentration= m x (1+ α) = 0.100 x (1 + 0.05)

concentration= 0.100 x (1 + 0.05) = 0.105m

$\Delta T_f = K_f \times m = 1.86 \times 0.105 = 0.1953$

T_f (solution) = 273.15K- 0.1953K= 272.95 K

(b)

π = i CRT

Calculation of Van't Hoff factor

CH_3COOH CH_3COO^- + H^+

1 0 0

1-α α α

i = 1+ α /1 = 1+ 0.03 / 1= 1.003

 = i CRT

 = 1.003 x 0.0821 x 300 x 0.02 = 0.494atm