UNIT 2

Solutions

Points to Remember

SOLUTION: A homogeneous mixture of two or more chemically non-reacting substances, whose composition can be varied within certain limits.

- A binary solution has two constituents one solute and one solvent.
- Solvent is the component present in largest amount and solute in smaller amount(in terms of moles).
- The solutions may be gaseous, liquid or solid depending upon the physical state of solvent.

CONCENTRATION OF SOLUTION

Mass% of a component (w/w)= (mass of solute/ total mass of solution)x100

Mass by volume percentage (w/v): mass of solute dissolved in 100 mL of the solution.

Volume percentage (v/v)% volume of solute per 100 mL of solution Volume%=(volume of solute/total volume of solution)×100

Mole fraction(χ): Ratio of no. of moles of one component to the total no. of the components present in the solution.
$\chi_A=n_A/n_A+n_B$, $\chi_B=n_B/n_A+n_B$, $\chi_A+\chi_B=1$
No unit, independent of temperature

Molality(m): No. of moles of solute per kg of the solvent.
Molality(m)=moles of solute/ mass of solvent in kg
Unit:mol/kg
Preferred over molarity for expressing concentration as it is independent of temperature.

Molarity(M): The number of moles of solute per litre or per dm^3 of the solution.
M=Moles of solute/volume of solution(in L) Unit: mol/L
• Changes with change in temperature due to change in volume of solution.

Parts per million (ppm): part of a component per million (10^6) parts of the solution. ppm=no. of parts of the component x10^6/total no. of parts of all components of the solution. It is used when a solute is present in trace quantities

HENRY'S LAW: "The partial pressure of the gas in vapour phase (*p*) is proportional to the mole fraction of the gas (χ) in the solution"

$p=K_H\chi$, K_H is Henry's law constant.

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

Applications of Henry's Law

(i) **Carbonated beverages:** To increase the solubility of CO_2 in soft drinks and soda water, the bottle is sealed under high pressure.

(ii) **In deep sea diving.** To avoid bends, toxic effects of high concentration of nitrogen in the blood, the tanks used by scuba divers are filled with air diluted with He.

(iii) **For climbers or people living at high altitude.** Concentration of O_2 in the blood and tissues is so low that they feel weak and are unable to think properly, a disease called anoxia.

RAOULT'S LAW

FOR A SOLUTION OF VOLATILE LIQUIDS: The partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution. If A and B are the two volatile components of solution then

$$p_A = p_A^0 \chi_A$$

$$p_B = p_B^0 \chi_B$$

Where p_A and p_B are partial vapour pressure of component 'A' and 'B' respectively in solution. p_A^0 and p_B^0 are vapour pressure of pure components 'A' and 'B' respectively.

FOR A SOLUTION CONTAINING NON-VOLATILE SOLUTE: The vapour pressure of the solution is directly proportional to the mole fraction of the solvent.

$$p_A \propto \chi_A$$

$$p_A = p_A^0 \chi_A$$

Effect of adding non-volatile solute on vapour pressure of a liquid. The vapour pressure of a liquid decrease if some non-volatile solute is dissolved in it because some molecules of the solvent on the surface are replaced by the molecules of the non-volatile solute.

- **Raoults' law becomes a special case Henry's law** in which K_H becomes equal to P_A^0, i.e., vapour pressure of pure solvent.

TYPES OF LIQUID-LIQUID SOLUTIONS ON THE BASIS OF RAOULT'S LAW

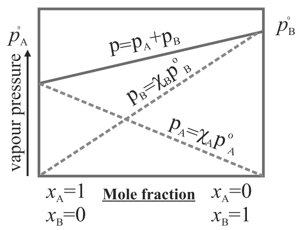
(Let A and B be the two liquids in solution.)

IDEAL SOLUTIONS

- Solutions which strictly obey Raoult's law over the entire range of concentration
- The interactions between solute and solvent are similar to those in pure components.

$$P_A = P_A^0 \chi_A,\ P_B = P_B^0 \chi_B$$
$$\Delta H_{mix} = 0$$
$$\Delta V_{mix} = 0$$

- Benzene + toluene, hexane + heptane, bromoethane + chloroethane



Graph for an ideal solution

NON-IDEAL SOLUTIONS

- Solutions which do not obey Raoult's law over the entire range of concentration
- The interactions between solute and solvent are different from those of pure components.

$$P_A \neq P_B^0 \chi_A \quad P_B \neq P_B^0 \chi_B$$
$$\Delta H_{mix} \neq 0$$
$$\Delta V_{mix} \neq 0$$

- Two types (i) Solutions showing positive deviations from Raoult's law.
  (ii) Solutions showing negative deviations from Raoult's law.

TYPES OF NON-IDEAL SOLUTIONS

NON-IDEAL SOLUTIONS SHOWING POSITIVE DEVIATION FROM RAOULT'S LAW

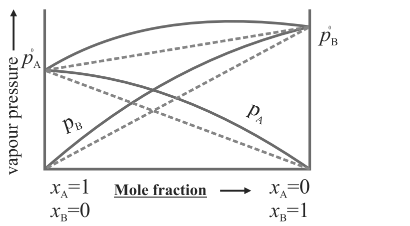
- solute - solvent interactions are weaker than solute - solute and solvent - solvent interaction

$p_A > p_A^0 \chi_A$; $p_B > p_B^0 \chi_B$

$\Delta_{mix}H > 0$

$\Delta_{mix}V > 0$

e.g. Acetone and ethanol, Water and ethanol, Acetone and benzene.



NON-IDEAL SOLUTIONS SHOWING NEGATIVE DEVIATION FROM RAOULT'S LAW

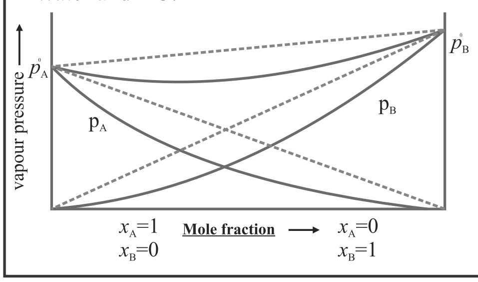
- solute - solvent interactions are stronger than solute - solute and solvent - solvent interaction

$p_A < p_A^0 \chi_A$; $p_B < p_B^0 \chi_B$

$\Delta_{mix}H < 0$

$\Delta_{mix}V < 0$

e.g. Acetone and aniline, Water and nitric acid, Water and HCl



AZEOTROPES

Liquid mixture, having the same composition, in liquid and vapour phase and boiling like a pure liquid is called a constant boiling mixture or an azeotropic mixture or an azeotrope.

MINIMUM BOILING AZEOTROPE

Minimum boiling azeotropes form when solutions exhibit positive deviation from Raoult's law. e.g. 95% ethanol - water mixture.

MAXIMUM BOILING AZEOTROPE

Maximum boiling azeotropes form when solutions exhibit negative deviation from Raoult's law. e.g. 68% nitric acid- water mixture.

COLLIGATIVE PROPERTIES

Physical properties of dilute solutions that depend upon the number of solute particles present in the solution irrespective of their nature.

RELATIVE LOWERING IN VAPOUR PRESSURE

$\chi_B = \frac{P_A^0 - P}{P_A^0}$

P_A^0 = Vapour pressure of solvent, P = Vapour pressure of solution

Where $P_A^0 - P/P_A^0$ is relative lowering in vapour pressure. χ_B = mole fraction of solute

$$\chi_B = \frac{n_B}{n_A + n_B}$$

For dilute solution, $n_B << n_A$, hence n_A is neglected in the denominator.

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

$$\frac{P_A^0 - P}{P_A^0} = \frac{w_B}{M_B} \times \frac{M_A}{w_A}$$

w_B = mass of solute, M_B = molar mass of solute
w_A = mass of solvent, M_B = molar mass of solvent

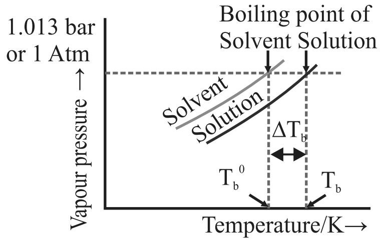
ELEVATION IN BOILING POINT (ΔT_b)

$\Delta T_b \propto m$, $\Delta T_b = k_b m$; m=molality

k_b = molal elevtion constant / Ebullioscopic constant. It is the elevation in boiling point when the molality of solution is unity. SI unit : K kg mol^{-1}

Elevation in boiling point and Molar mass of solute $M_B = k_b\ 1000 w_B / \Delta T_b W_A$

M_B=Molar mass of solute, w_B = mass of solute, w_A= mass of solvent (in gram)



COLLIGATIVE PROPERTIES

DEPRESSION IN FREEZING POINT (ΔT_f)

$\Delta T_f \propto m$, $\Delta T_f = K_f.m$

K_f = molal depression constant / Cryoscopic constant. It is the depression in freezing point when the molality of solution is unity. SI unit : K kg mol^{-1}

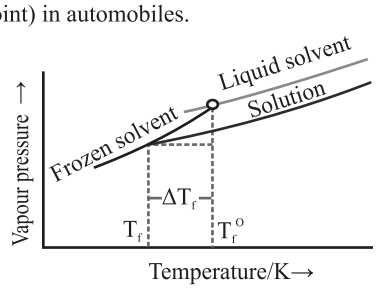
Depression in freezing point and Molar mass of solute

$M_B = k_f\ 1000 w_B / \Delta T_f w_A$

M_B= Molar mass of solute, w_B = mass of solute,

W_A=mass of solvent (in gram)

APPLICATION : Ethylene glycol is used as antifreeze (causes depression in freezing point) in automobiles.



n_B

OSMOTIC PRESSURE (π)

The excess pressure that must be applied to a solution side to prevent osmosis i.e. to stop the passage of solvent molecules into it through semi-permeable membrane is called osmotic pressure.

$\pi \propto C$, $\pi \propto T$, $\pi = CRT$,

C = Molarity of solution, $C = n_B/V$, V=volume of solution (L), n_B=no. of moles of solute

$\pi V = n_B RT$

$\pi = w_B RT/M_B V$

R=0.0821L atm K^{-1} mol^{-1} ; T=Temperature in Kelvin

ISOTONIC SOLUTIONS

Two solutions having same osmotic pressure at a given temperature are called isotonic solutions. **Hypertonic solution** have higher osmotic pressure and **Hypotonic solution** have lower osmotic pressure than the other solution. 0.91% of sodium chloride is isotonic with fluid present inside human red blood cells.

REVERSE OSMOSIS- If a pressure higher than osmotic pressure is applied on the solution the solvent will flow from the solution into the pure solvent through the semi permeable membrane. It is used in the desalination of sea water.

Abnormal Molar Masses

The molar mass of a substance determined by studying colligative properties comes out to be different from their normal values, the substance is said to show abnormal molar mass.

The anomalies in molar masses or colligative properties for electrolytes are mainly due to

(i) Dissociation of molecules (ii) Association of molecules

van't Hoff factor (*i*)

van't Hoff factor (i) is defined as the ratio of the experimental value of the colligative property to the calculated value of the colligative property.

$$i = \frac{\text{Observed colligative property}}{\text{Calculated colligative property}}$$

OR

$$i = \frac{\text{Total number of moles of particles after association/dissociation}}{\text{Number of moles of particles before association/dissociation}}$$

OR

$$i = \frac{\text{Normal (calculated) molar mass}}{\text{Abnormal (observed) molar mass}}$$

Case I

In case of association, observed molar mass being more than the normal, the factor (i) has value less than 1 [$i < 1$]

Case II

In case of dissociation, observed molar mass being less than the normal molar mass, the factor(i) has value greater than 1. [$i > 1$]

Case III

In case there is no association or dissociation the value of *i* becomes equal to one.

OBJECTIVE TYPE QUESTIONS

I MULTIPLE CHOICE QUESTIONS

1. The molarity of 98% H_2SO_4 (density= 1.8 g/mL) by weight is:
   (a) 6 M (b) 18 M
   (c) 10 M (d) 4 M
2. Which of the following does not show positive deviation from Raoult's law?
   (a) benzene + chloroform (b) benzene + acetone
   (c) benzene + ethanol (d) benzene + CCl_4
3. Which solution will have least vapour pressure?
   (a) 1 M glucose (b) 2 M glucose
   (c) 3 M glucose (d) 4 M glucose
4. Which condition is not satisfied by an ideal solution?
   (a) $\Delta_{mix} H = 0$ (b) $\Delta_{mix} V = 0$
   (c) $\Delta_{mix} P = 0$ (d) $\Delta_{mix} S = 0$
5. Azeotrope mixture are:
   (a) mixture of two solids
   (b) those will boil at different temperature
   (c) those which can be fractionally distilled
   (d) constant boiling mixtures
6. Which is temperature independent term?
   (a) w/w% (b) v/v%
   (c) w/v% (d) Molarity
7. Solute when dissolve in water
   (a) increases the vapour pressure of water
   (b) decreases the boiling point of water
   (c) decrease the freezing point of water
   (d) All of the above
8. The plant cell will shrink when placed in:
   (a) water (b) a hypotonic solution
   (c) a hypertonic solution (d) an isotonic solution

9. Two aqueous solutions S_1 and S_2 are separated by a semi-permeable membrane. S_2 has lower vapour pressure than S1 of a non -volatile solute, Then
   a) more solvent will flow from S_1 to S_2
   b) more solvent will flow from S_2 to S_1
   c) solvent from S_1 and S_2 will flow at equal rates
   d) no flow will take place
10. Temperature dependent concentration term is :
    (a) M (b) m
    (c) *x* (d) All of these
11. Which of the fo1lowing solutions would have the highest osmotic pressure:
    (a) M/10 NaCl (b) M/10 Urea
    (c) M/10 $BaCl_2$ (d) M/10 Glucose
12. 0.5 M aqueous solution of glucose is isotonic with:
    (a) 0.5 M KCl solution (b) 0.5 M $CaCl_2$ solution
    (c) 0.5 M Urea solution (d) 1 M solution of sucrose
13. Which of the following is true for Henry's constant ?
    (a) lt decreases with temperature
    (b) It increases with temperature
    (c) Independent on temperature
    (d) It do not depend on nature of gases.
14. Which one is the best colligative property for determination of molecular mass of polymer?
    (a) osmotic pressure (b) elevation in boiling point
    (c) depression in freezing point (d) osmosis
15. An azeotropic solution of two liquids has boiling point lower than either of them when it
    a) shows negative deviation from Raoult's Law
    b) shows no deviation from Raoult's Law
    c) shows positive deviation from Raoult's Law
    d) is saturated
16. Henry's law constant K_H of CO_2 in water at 25°C is 3 x 10^{-2} mol/L atm^{-1}. Calculate the mass of CO_2 present in 100 L of soft drink bottled with a partial pressure of CO_2 of 4 atm at the same temperatrue.
    (a) 5.28 g (b) 12.0 g
    (c) 428 g (d) 528 g

17. If osmotic pressure of 1 M urea is π, what will be the osmotic pressure for 2 M urea?

    (a) π (b) 0.1π

    (c) 2π (d) 0.2π

18. The most likely an ideal solution is:

    (a) NaCl-H_2O (b) C_2H_5OH-C_6H_6

    (c) C_7H_{16} - H_2O (d) C_7H_{16} -C_8H_{18}

19. $\Delta_{mix}H$ for solution of $CHCl_3$ and CH_3COCH_3 is.

    (a) positive (b) 0

    (c) negative (d) None of these

20. The solutions A, B, C and D are respectively 0.1 M glucose, 0.05 M NaCl, 0.05 M $BaCl_2$ and 0.1 M $AlCl_3$. which one of the following pairs is isotonic?

    (a) A & C (b) B & C

    (c) C & D (d) A & B

21. Which one of the following pairs will form an ideal solution?

    (a) Chloroform and acetone (b) Ethanol and acetone

    (c) n-hexane and n-heptane (d) Phenol and aniline

22. An azeotropic solution of two liquids has a boiling point lower than either of the two when it ?

    (a) shows a positive deviation from Raoult's law

    (b) shows a negative deviation from Raoult's law.

    (c) shows no deviation from Raoult's law.

    (d) is saturated.

23. Which of the following formula represents Raoult's law for a solution containing non-volatile solute?

    (a) $P_{solute} = P^0_{solute} \times X_{solute}$

    (b) $P = K_H \cdot X$

    (c) $P_{Total} = P_{solvent}$

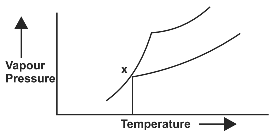
    (d) $P_{solute} = P^0_{solvent} \times X_{solvent}$

24. On mixing 20mL of acetone with 30 mL of chloroform, the total volume of the solution is

    (a) <50mL (b) =50mL

    (c) >50mL (d) =10mL

25. Elevation of boiling point in inversely proportional to
    (a) molal elevation constant(K_b) (b) molality (m)
    (c) molar mass of solute(M) (d) weight of solute (w)
26. An unknown gas 'X' is dissolved in water at 2.5 bar pressure and has mole fraction 0.04 in solution. The mole fraction of 'X' gas when the pressure of gas is doubled at the same temperature is
    (a) 0.08 (b) 0.04
    (c) 0.02 (d) 0.92
27. The boiling point of a 0.2 m solution of a non-eletrolyte in water is (k_b for water = 0.52 kg mol^{-1})
    (a) 100^0C (b) 100.52^0C
    (c) 100.104^0C (d) 100.26^0C
28. In the following diagram point, 'X' represents



    (a) Boiling point of solution (b) Freezing point of solvent
    (c) Boiling point of solvent (d) Freezing point of solution
29. A compound undergoes complete tetramerization in a given organic solvent. The van't Hoff factor 'i' is:
    (a) 4.0 (b) 0.25
    (c) 0.125 (d) 2.0

II <u>FILL IN THE BLANKS</u>

1. The sum of mole fractions of all the components in a three component system is equal to......................
2. A Solution which distill without change in composition is called ....
3. Desalination of sea water is based on the phenomenon of......................
4. Relative lowering in vapour pressure is equal to the mole fraction of ....
5. The evaporation of aqueous solution of glucose causes its molarity to ....
6. The boiling point of sea water at 1atm pressure is .... that of distilled water.
7. The ratio of observed value of colligative property to the calculated value of colligative property is called ....
8. The most suitable colligative property to measure molecular mass of polymers is.............

9. People taking a lot of salt develop swelling or puffiness of their tissues. This disease is called.............
10 . If observed molar mass of a solute is more than calculated molar mass, then the solute undergoes................. in solution.

III <u>**ASSERTION REASON TYPE QUESTIONS**</u>

(a) Both assertion and reason are correct statements, and reason is the correct explanation of the assertion.

(b) Both assertion and reason are correct statements, but reason is not the correct explanation of the assertion.

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

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

1. **Assertion:** Molality is a better method to express concentration than molarity.
   Reason: Molality is defined in terms of mass of solvent and not volume of solution .
2. **Assertion:** Soda bottles are sealed under high pressure.
   Reason: High pressure increases the solubility of carbon dioxide gas in solution .
3. **Assertion:** Non-ideal solutions always form azeotropes.
   Reason: Boiling point of an azeotrope may be lower or higher than boiling points of both components.
4. **Assertion:** Benzene and hexane form an ideal solution.
   Reason : Both benzene and hexane are hydrocarbons.
5. **Assertion:** 1 molar NaCl solution has higher boiling point than one molar urea.
   Reason: NaCl dissociates into ions in solution .
6. **Assertion:** Two solutions having same osmotic pressures will also have same vapour pressures.
   Reason: Lowering of vapour pressure is not a colligative property .
7. **Assert ion :** Helium is mixed with nitrogen and oxygen in diving cylinders
   Reason: Helium has comparatively low solubility in blood.
8. **Assertion:** NaCl or $CaCl_2$ is used to clear snow on roads in the hills.
   Reason: The salts depress the freezing point of water.

9. **Assertion:** Molar mass of acetic acid in benzene calculated using colligative property is almost double the actual value.

   Reason: Acetic acid dimerises in solution.

10. **Assertion:** Vapour pressure of a solution is more that of the pure solvent.

    Reason: The solute particles occupy certain area of the surface of the solution which reduces the amount of vapour.

11. **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.

IV ONE WORD ANSWER TYPE QUESTIONS

1. Which of the following is a dimension less quantity : molarity, molality or mole fraction?
2. Liquid 'Y' has higher vapour pressure than liquid 'X' . Which of them will have higher boiling point?
3. N_2 and O_2 gases have K_H values 76.48 kbar an d 34.86 kbar respectively at 293 K temperature. Which one of these will have more solubility in water?
4. Name for k_b is___________.
5. Mention the unit of ebullioscopic constant (molal boiling point elevation constant).
6. What type of deviation from Raoult's law is exhibited the solution forming minimum boiling azeotrope?
7. For reverse osmosis to take place external pressure applied must be lesser than or greater than osmotic pressure?
8. Name the law which can explain the solubility of gases in liquids at different pressures.
9. Out of molarity and molality which is preferred for expressing the concentration of solution?
10. A decrease in temperature is observed on mixing ethanol and acetone. What type of deviation from Raoult's law is this?
11. What is the sum of the mole fractions of all the components in a three component system?
12. 10 cm^3 of a liquid A was mixed with 10 cm^3 of liquid B. The volume of the resulting solution was found to be 19.9 cm^3.What do you conclude?
13. Name the disease caused by low concentration of oxygen in the blood and tissues of people living at high altitude.
14. Mention a large scale use of reverse osmosis.
15. Under which conditon van't Hoff factor is less than one.

VERY SHORT ANSWER TYPE QUESTIONS (1 Mark Questions)

Q.1. What is van't Hoff factor ?

Ans. It is the ratio of normal molecular mass to observed molecular mass. It is denoted as *i*.

i = normal molecular mass/observed molecular mass

= no. of particles after association or dissociation/no. of particles before dissociation or association

Q.2. What is the van't Hoff factor in $K_4[Fe(CN)_6]$ and $BaCl_2$?

Ans. 5 and 3

Q.3. Why the molecular mass becomes abnormal ?

Ans. Due to association or dissociation of solute in given solvent.

Q.4. What role does the molecular interaction play in the solution of alcohol and water ?

Ans. Positive deviation from ideal behaviour.

Q.5. What is van't Hoff factor ? How is it related with :

(a) degree of dissociation (b) degree of association

Ans. It is the ratio of normal molecular mass to observed molecular mass. It is denoted as *i*.

i = normal molecular mass/observed molecular mass

i = no. of particles after association or dissociation/no. of particles before dissociation or association

(a) $\alpha = \frac{i - 1}{n-1}$ (b) $\alpha = \frac{i - 1}{1/n-1}$

Q.6. Why NaCl is used to clear snow from roads ?

Ans. It lowers freezing point of water.

Q.7. Why the boiling point of solution is higher than pure liquid ?

Ans. Due to lowering in vapour pressure.

Q.8. Henry's law constant for two gases are 21.5 and 49.5 atm, which gas is more soluble ?

Ans. K_H is inversely proportional to solubility.

Q.9. Define azeotrope. Give an example of maximum boiling azeotrope.

Hint: Refer "Points to remember"

Q.10. Calculate the volume of 75% of H_2SO_4 by weight (d = 1.8 g/mL) required to prepare 1 L of 0.2 M solution.

Hint: $M_1 = \frac{\text{Mass \%} \times d \times 10}{98}$

$M_1V_1 = M_2V_2$

= 14.5 mL

Q.11. Why water cannot be completely separated from aqueous solution of ethyl alcohol ?

Ans. Due to formation of azeotrope at (95.4%).

Q.12. Why anhydrous salts like NaCl or $CaCl_2$ are used to clear snow from roads on hills ?

Hint : They depress freezing point of water.

Q.13. What is the effect on boiling and freezing point of a solution on addition of NaCl ?

Hint : Boiling point increases and freezing point decreases.

Q.14. Why osmotic pressure is considered as colligative property ?

Hint : It depends upon number of moles of solute present in solution.

Q.15. Liquid A and B on mixing produce a warm solution. Which type of deviation does this solution show ?

Hint : — ve deviation for from Raoult's law

Q.16. Give an example of a compound in which hydrogen bonding results in the formation of a dimer.

Hint : Carboxylic acids

Q.17. What role does the molecular interaction play in solution containing chloroform and acetone ?

Hint : H-bonding formed, results in negative deviation from Raoult's law.

Q.18. What is meant by 5% Na_2CO_3 solution (w/w)?

Ans. 5% *w*/w means 5g Na_2CO_3 dissolves in 100 g solution.

Q.19. What will be the mole fraction of C_2H_5OH in aqueous solution of C_2H_5OH when solution contain equal number of moles of water and C_2H_5OH?

Ans. Solution is equimolar, it means mole fraction of each component is 0.5.

Q.20. If at the same temperature, hydrogen is more soluble in water than helium, which of them will have a higher value of K_H?

Ans. As H_2 is more soluble than helium, so H_2will have lower value of K_H than that of helium.

Q.21. State the formula relating to the pressure of a gas with its mole fraction in a liquid solution in contact with it

Hint: $p = K_H . x$

Q.22. If K_f for water is 1.86 K kgmol^{-1}, what is the boiling point of 0.01 molal aqueous solution of a substance which undergoes neither association nor dissociation?

Ans. $\Delta T_b = i\, K_b \,.\, m$

$\Delta T_b = 1 \times 1.86 \times 0.01 = 0.0186$

$= 100.0186°C$

Q.23. Why does sodium chloride solution freeze at a lower temperature than water?

Hint: NaC1 being non-volatile solute , decreases the vapour pressure and therefore decreases the freezing point.

Q.24. Out of 0.1 molal solution of glucose and NaCl, which one will have a higher boiling point and why?

Ans. 0.1 m NaC1 solution will have higher boiling point because it dissociates in the solution. As a result, number of moles of the solute in solvent is higher in case of NaCl than glucose.

Q.25. Ionic compounds are soluble in water but they are insoluble in organic solvents.

Give reason.

Hint: "Like dissolves like”

SHORT ANSWER TYPE QUESTIONS (2 or 3 Marks Questions)

Q.1. State Henry's law. What is the significance of K_H ?

Ans. **Henry's Law:** It states that "the partial pressure of the gas in vapour phase (p) is directly proportional to the mole fraction of the gas (x) in the solution", and is expressed as : $p=K_H\, x$ where, K_H is the Henry's Law constant

Significance of K_H : Higher the value of Henry's law constant K_H, the lower is the solubility of the gas in the liquid.

Q.2. How is that measurement of osmotic pressure is more widely used for determining molar masses of macromolecules than the elevation in boiling point or depression in freezing point of their solutions?

Ans : The osmotic pressure method has the advantage over elevation in boiling point or depression in freezing point for determining molar masses of macromolecules because

1. Osmotic pressure is measured at the room temperature and the molarity of solution is used instead of molality.

2. Compared to other colligative properties, its magnitude is large even for very dilute solutions.

Q.3. Equal moles of liquid P and Q are mixed. What is the ratio of their moles in the vapour phase? Given that $P_p°$ = 2 x $P_q°$.

Hint: Since equal moles of P and Q are mixed

⇒ Mole fraction of P = Mole fraction of Q = × = 1/2

$P_p = p°_p \times 1/2 = 2 \times P_q^\circ \times 1/2 = P_q^\circ$

$P_q = P°_q \times 1/2 = P_q^\circ /2$

- In vapour phase, let the total pressure be P

⇒ $y_1 = P_p / P = P_q^0 / p$

⇒ $y_2 = P_q / P = (P^\circ_q/2) / P$

⇒ $y_1/y_2 = 2/1$

- Ratio of moles of P and Q in vapour phase = $y_1 : y_2 = 2 : 1$

⇒ **P:Q = 2:1**

Q.4. On mixing liquid X and Y, volume of the resulting solution decreases. What type of deviation from Raoult's law is shown by the resulting solution ? What change in temperature would you observe after mixing liquids X and Y ?

Hint: Negative; Increase in temp.

Q.5. Explain the significance of Henry's constant (K_H). At the same temperature, hydrogen is more soluble in **water than helium. Which of them will have higher value of K_H and why ?**

Hint: Significance of K_H Higher the value of Henry's law constant K_H ,the lower is the solubility of the gas in the liquid ; He has higher value of K_H

Q.6. How many grams of KCl should be added to 1 kg of water to lower its freezing point to — 8.0°C ? (K_f =1.86 K kg mol^{-1})

Ans. Since KCl dissociate in water completely, i = 2.

$\Delta T_f = iK_f.m$

$m = \Delta T_f / i\,K_f$

$= \frac{8}{2 \times 1.86}$

m = 2.15 mol/kg

Grams of KCl = 2.15 × 74. = 160.2 g/kg

Q.7. Why is freezing point depression of 0.1 M sodium chloride solution nearly twice that of 0.1 M glucose solution?

Hint: Colligative properties α number of particles.

NaCI is a strong electrolyte and gives two particles on dissociation, but glucose being non-electrolyte does not dissociate and remains as a single particle

Q.8. a) Why is an increase in temperature observed on mixing chloroform and acetone?

b) Why does sodium chloride solution freeze at a lower temperature than water?

Ans: a) The bonds between chloroform molecules and molecules of acetone are dipole-dipole interactions but on mixing, the chloroform and acetone molecules, they start forming hydrogen bonds which are stronger bonds resulting in the release of energy. This gives rise to an increase in temperature.

b) When a non- volatile solute is dissolved in a solvent, the vapour pressure decreases. As a result, the solvent freezes at a lower temperature.

Q.9. Define reverse osmosis. Write its one use.

Hint: If the pressure applied on the solution is greater then the osmotic pressure than the solvent molecules start to move from solution into solvent through a semipermeable membrane this process called the reverse osmosis. ; Desalination of water.

Q.10.Why does an azeotropic mixture distills without any change in composition ?

Hint : It has same composition of components in liquid and vapour phase.

Q.11.Under what condition Van't Hoff factor is :

(a) **equal to 1 ? (b) less than 1 ? (c) more than 1 ?**

Hint: (a) When the solute neither associates nor dissociates in solution , i is equal to I.

(b)When the solute under goes association in solution , i is less than 1.

(c) When the solute under goes dissociation in solution , i is more than 1.

Q.12. An aqueous solution of 2% non-volatile exerts a pressure of 1.004 Bar at the normal boiling point of the solvent. What is the molar mass of the solute ?

Hint:

$$\frac{P^o_A - P_A}{P^o_A} = \frac{W_B \times m_A}{m_B \times w_A}$$

$$\frac{1.013 - 1.004}{1.013} = \frac{2 \times 18}{m_B \times 98}$$

$$m_B = 41.35 \text{g/mol}$$

Q.13. Why is it advised to add ethylene glycol to water in a car radiator in hill station ?

Hint: Anti-freeze.

Q.14. Calculate the molarity of pure water (*d* = **1 g mL^{-1}**)**.**

Ans. Density of water = 1 g mL^{-1}

Mass of 1000 mL of water = V × *d*

= 1000 mL × **1** g/mL

= 1000 g

Moles of water = $\frac{1000}{18}$ = 55.55 mol

Now, mole of H_2O present in 1000 mL or **1 L** of water.

So, molarity = 55.55M

Q.15. Define Henry's law. Give their two applications.

Hint: Refer"Points to remember"

Q.16. The dissolution of ammonium chloride in water is endothermic process. What is the effect of temperature on its solubility ?

Ans. Since dissolution of NH_4C1 in water is endothermic process, its solubility increases with rise in temperature *(i.e.,* Le-Chatelier principle).

Q.17. Two liquids A and B boil at 145°C and 190°C respectively. Which of them has higher vapour pressure at 80°C ?

Ans. Lower the boiling point more volatile is the respective compound. Therefore, liquid A will have higher vapour pressure at 80°C.

Q.18. Why is liquid ammonia bottle first cooled in ice before opening it ?

Ans. At room temperature, the vapour pressure of liquid ammonia is very high. On cooling vapour pressure decreases, therefore the liquid ammonia will not splash out.

Q.19 Determine the amount of $CaCl_2$ dissolved in 2.5L at 27°C such that its osmotic pressure is 0.75 atm at 27°C. (*i* for $CaCl_2$ = 2.47)

Ans. For $CaCl_2$,

$$i = 2.47$$

$$\pi = iCRT$$

$$= i \frac{n_B}{V} \times RT$$

$$0.75 = \frac{2.47 \times n_B \times 0.082 \times 300}{2.5}$$

$$n = \frac{0.75 \times 2.5}{2.47 \times 0.082 \times 300}$$

n_B= 0.0308 mol

Amount of $CaCl_2$ = 0.0308 mol × 111g mol^{-1}

= 3.418g

Q.20. Determine the osmotic pressure of a solution prepared by dissolving 25 mg of K_2SO_4 in 2 litre of water at 25°C assuming that it is completely dissociated.

Ans. If K_2SO_4 is completely dissociated,

$K_2SO_4 \Rightarrow 2K^+ + SO_4^{2-}$

i =3

Mol mass of K_2SO_4 = 2 × 39 + 32 + 4 × 16= 174 g mol^{-1}

$$\pi = iCRT$$

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

$$= \frac{3 \times 25 \times 10^{-3} \times 0.082 \times 298}{174 \times 2.0}$$

$= 5.27 \times 10^{-3}$ atm

Q.21. If the solubility product of CuS is 6 x 10^{-16}, calculate the maximum molarity of CuS in aqueous solution.

Ans. K_{sp} of CuS = 6 × $\mathbf{10^{-16}}$

If S is the solubility, then

CuS —> $Cu^{2+} + S^{2-}$

$[Cu^{2+}]$ = S, $[S^{2-}]$ = S

K_{sp} = $[Cu^{2+}][S^{2-}] = S \times S = S^2$

Solubility S = $\sqrt{K_{sp}} = \sqrt{6 \times 10^{-16}}$

= 2.45×10^{-8} M

Highest molarity = 2.45×10^{-8} M

Q.22 Suggest the most important type of intermolecular attractive interaction in the following pairs:

(a) n-hexane and n-octane (b) I_2. and CCl_4

(c) $NaC1O_4$ and water

Ans. (a) van der Waals interaction

(b) van der Waals interaction

(C) Ion-dipole interaction

23. The vapour pressure of water is 12.3 kPa at 300K. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it.

Ans. Mole fraction of solute =

$$\frac{1}{1+\frac{1000}{18}} = 0.0177$$

$$\frac{P_A^0 - P}{P_A^0} = 0.0177$$

$$\frac{12.3 - P_A}{12.3} = 0.0177$$

$$P_A = 12.08 \text{ Kpa}$$

Q.24. 6.90M solution of KOH in water contains 30% by mass of KOH. Calculate the density of the KOH solution. (Molar mass of KOH = 56 g mol^{-1})

Ans. Mass of KOH = 30 g

$$M = \frac{n_B}{v(mL)} \times 1000$$

$$= \frac{W_B}{M_B \times V(mL)} \times 1000 = \frac{30}{56 \times V} \times 1000$$

$$6.90 = \frac{30 \times 1000}{56 \times V}$$

$$V = \frac{30 \times 10000}{56 \times 6.90} = 81.43 mL$$

$$d = \frac{M}{V}$$

$$= \frac{100}{81.43} = 1.28 gmL^{-1}$$

Q.25. An anti-freeze solution is prepared from 222.6 g of ethylene glycol $C_2H_4(OH)_2$ and 200 g of water. Calculate the molality of the solution. If the density of this solution be 1.072 g L^{-1}, what will be the molarity of the solution ?

Ans. M_B of $C_2H_4(OH)_2$ = 62 $gmol^{-1}$

$$\text{Molality} = \frac{n_B}{W_A} \times 1000 = \frac{W_B}{M_B x W_B} \times 1000 = \frac{222.6x1000}{56x200}$$

$$= 17.95m$$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{So, Volume} = \frac{\text{Mass}}{\text{Density}} = \frac{422.6}{1.072} = 394.22 \text{ mL}$$

$$M = \frac{n_B}{V} \times 1000$$

$$= \frac{222.6}{394.22 \times 62} \times 1000 = 9.11M$$

Q.26. What would be the molar mass of compound if 6.21 g of it is dissolved in 24.0g of $CHCl_3$ from a solution that has a boiling point of 68.04°C. The boiling point of pure chloroform is 61.7°C and the boiling point elevation constant K_b for chloroform is 3.63°C/m.

Ans. Elevation in boiling point ΔT_b= 68.04 — 61.7 = 6.34°C

Mass of substance W_B = 6.21 g

Mass of $CHC1_3$ W_A = 24.0 g

K_B = 3.63 °C/m

$$M_B = \frac{K_b \times W_B \times 1000}{\Delta T_b \times W_A} = \frac{3.63 \times 6.21 \times 1000}{6.34 \times 24}$$

$$= 148.15 g\ mol^{-1}$$

Q.27 A solution of glycerol ($C_3H_8O_3$) in water was prepared by dissolving some glycerol in 500 g of water. This solution has a boiling point of 100.42°C while pure water boils at 100°C. What mass of glycerol was dissolved to make the solution ? (K_b= 0.512 K kg mol^{-1})

Ans. Given w_1= 500g

Boiling point of solution(T_b)=100.42^{0}C

$K_b(H_2O)$=0.512Kkgmol^{-1}

$M_2(C_3H_8O_3)=3\times12+8\times1+3\times16=92$gmol^{-1}

$\Delta T_b=T_b-T_b^0=373.42-373K=0.42K$

As we know $\Delta T_b = \frac{K_b.w_2\times1000}{M_2\times w_1} \Rightarrow w_2 = \frac{\Delta T_b\times M_2\times w_1}{K_b\times100}$

$$w_2= \frac{0.42K\times92g\ mol^{-1}\times500g}{0.512\ Kkg\ mol^{-1}\times1000gkg^{-1}} =37.73g$$

Q.28. 18 g of glucose ($C_6H_{12}O_6$) (molar mass = 180 g mol^{-1}) is dissolved in 1 kg of water in a saucepan. At what temperature will this solution boil ? for water = 0.52 K kg pure water = 373.1 K)

Ans. According to question,

M_1=18g mol^{-1}

M_2=180g mol^{-1}

w_1=1kg=1000g

w_2=18g K_b=0.52 K kg mol^{-1}

We know that $\Delta T_b= K_b. \frac{w_2}{M_2}\times\frac{1000}{w_1}$

or $$\Delta T_b=0.52\ K\ kg\ mol^{-1}\times\frac{18g}{180g\ mol^{-1}}\times\frac{1000kg^{-1}}{1000g}=0.052K$$

Since water boils at 373.15 K at 1.013 bar pressure, therefore, the boiling point of solution will be 373.15+0.052=373.202 K

LONG ANSWER TYPE QUESTIONS (5 Marks)

Q.1 (a) Define Raoult's law of binary solution containing non-volatile solute in it.

(b) On dissolving 3.24 g of sulphur in 40 g of benzene, boiling point of solution was higher than that of benzene by 0.81K (K_b = 2.53 K kg mo1^{-1}). What is molecular formula of sulphur ? (Molar mass of sulphur = 32 g mol^{-1})

Ans.(a) At a given temperature, the vapour pressure of a solution containing non-volatile solute is directly proportional to the mole fraction of the solvent.

(b)

$$M_B = \frac{K_b.w_2 x1000}{\Delta T_b x W_A} = \frac{2.53x3.24 \times 1000}{0.81x40}$$

$$= 253 \text{ g mol}^{-1}$$

Let the molecular formula of sulphur = S_x

Atomic mass of sulphur = 32

Molecular mass = 32 × x

$32x = 253$

$x = 7.91 \approx 8$

Molecular formula of sulphur = S_8

Q.2(a) Outer shells of two eggs are removed. One of the egg is placed in pure water and the other is placed in saturated solution of NaCl. What will be observed and why ?

(b) A solution prepared by dissolving 8.95 mg of a gene fragment in 35.0 ml of water has an osmotic pressure of 0.335 torr at 25°C.Assuming the gene fragment is a non-electrolyte, determine the molar mass.

Ans. (a) In pure water the egg swells and in saturated solution of NaCl it will shrinks.

(b) Mass of gene fragment = 8.95 mg

= 8.95×10^{-3}g

Volume of water = 35.0 mL = 35×10^{-3} L

π = 0.335 torr = 0.335/760 atm

Temp = 25 + 273 = 298 K

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

$$\frac{0.335}{760} = \frac{8.95 \times 10^{-3} \times 0.0821 \times 298}{M_B \times 35 \times 10^{-3}}$$

M_B= 14193.3 g mol^{-1}

Q.3 (a) **Define van't Hoff factor.**

(b) Calculate the freezing point depression expected for 0.0711M aqueous solution of Na_2SO_4. If this solution actually freezes at — 0.320°C, what would be the value of van't Hoff factor ?(K_f = 1.86°C mol^{-1})

Ans.(a) **van't Hoff factor :** It is the ratio of the normal molar mass to the observed molar mass of the solute.

(b) $\Delta T_f = K_f \times m$

$\Delta T_f = 1.86 \times 0.0711 = 0.132$

Observed freezing point = 0 – (–0.320) = 0.320°C

$$i = \frac{\text{Observed freezing point}}{\text{Calculate freezing point}}$$

$$= \frac{0.320}{0.132} = 2.42$$

Q.4. (a)**What is the value of *i* when solute is associated and dissociated ?**

(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, K_f = 1.86 K kg mol^{-1})**

Ans. (a) $i < 1$ when solute is associated and

$i > 1$ when solute is dissociated.

(b) $$m = \frac{n_g \times 1000}{W_A(g)}$$

$$= \frac{W_b \times 1000}{W_B \times W_A} = \frac{10.50 \times 1000}{184 \times 200} = 0.2853\text{M}$$

$MgBr_2$ ionizes as $MgBr_2 \rightarrow Mg^{2+} + 2Br^-$

$i = 3$

$\Delta T_f = i \times K_f \times m$

$= 3 \times 1.86 \times 0.2853$

$= 1.59$

Freezing point = 0 – 1.59°C = –1.59°C

Q.5 (a) What is the value of *i* for $Al_2(SO_4)_3$ when it is completely dissociated ?

(b) Calculate the boiling point of a solution prepared by adding 15.00 g of NaCl to 250 g of water. (K_b = 0.512 K kg mol^{-1} and molar mass of NaCl = 58.44 g mol^{-1})

Ans. (a) $Al_2(SO_4)_3 \rightarrow 2Al^{3+} + 3SO_4^{2-}$

$i = 5$

(b) $$\Delta T_b = \frac{iK_b \times 1000 \times W_B}{W_A \times M_B}$$

$NaCl \rightarrow Na^+ + Cl^-$

$i = 2$

$$\Delta T_b = \frac{2 \times 0.512 \times 1000 \times 15}{250 \times 58.44}$$

$= 1.05$

Boiling Point of solution = 100 + 1.05 = 101.05^{0}C

Q.6 (a) Calculate the freezing point of solution when 1.9 g of $MgCl_2$ (M = 95g mol^{-1}) was dissolved in 50g of water, assuming $MgCl_2$ undergoes complete ionization. (K_f for water = 1.86K kg mol^{-1}).

(b) *(i)* Out of 1 M glucose and 2 M glucose, which one has a higher boiling point and why?

ii*)* What happens when the external pressure applied becomes more than the osmotic pressure of solution?

Ans. (a)

$$\Delta T_f = \frac{iK_f \times w_B \times 1000}{M_B \times w_A}$$

$$\Delta T_f = 3 \times (1.86 \times 1.9/95 \times 50) \times 1000 = 2.23K$$

$$T_f^{\circ} - T_f = 2.25 \text{ K}$$

$$273.15 - T_f = 2.23$$

$$T_f = 270.92 \text{ K}$$

(b) (i) 2 M glucose; More number of particles/less vapour pressure

(ii) Reverse osmosis

Q.7. (a) When 2.56 g of sulphur was dissolved in 100 g of CS_2, the freezing point lowered by 0.383 K. Calculate the formula of sulphur S_x [K_f for CS_2 = 3.83 K Kg mo1^{-1}. Atomic mass of sulphur = 32 g mo1^{-1}]

(b) Blood cells are isotonic with 0.9% sodium chloride solution. What happens if we place blood cells in *a* solution containing.

(i) 1.2% sodium chloride solution?

(ii) 0.4% sodium chloride solution?

Ans. (a)

$$\Delta T_f = \frac{K_f \times w_b \times 1000}{M \times w_a}$$

$$0.383 = \frac{3.83 \times 2.56 \times 1000}{M \times 100}$$

$$M = 256$$

Let molecular formula of sulphur = Sx, its mol mass = 32x

$$\therefore \quad 32x = 256$$

$$x = 8, \quad S_8$$

(b) (i) Shrinks (ii) Swells

Q.8. (a) How will you determine the molecular mass from the relative lowering of vapour pressure?

(b)) At 298 K, the vapour pressure of water is 23.75 mm Hg. Calculate the vapour pressure at the same temperature over 5% aqueous solution of urea NH_2CONH_2.

Hint: (i) Refer "Points To Remember"

(ii) According the Raoult's law,

Subtituting the values, we have $\frac{P^0 - P_s}{P^o} = \frac{w_2}{M_2} \times \frac{M_2}{w_1}$

$$\frac{23.75 - P_s}{23.75} = \frac{5 \times 18}{60 \times 95}$$

$$\Rightarrow \quad 23.75 - P_s = \frac{5 \times 18}{60 \times 95} \times 23.75 = 0.375$$

$$\therefore \quad P_s = 23.75 - 0.375 = 23.375 \text{ mm}$$

Q9. (a) List three points of differences between ideal solution and non-ideal solution.

(b) Calculate the boiling point elevation for a solution prepared by adding 10 g of $CaCl_2$ to 200 g of water. (K_b for water = 0.512 K kg mol^{-1}, Molar mass of $CaCl_2$ =111 g mol^{-1})

(a) Refer " Points to remember"

(b) $\Delta T_f = i\, K_b\, m = i\, K_b . \frac{w_2}{M_2} \times \frac{1000}{w_1}$

For $CaCl_2; i = 2$

$K_b = 0.512$ K kg mol^{-1}

$$\Delta T_b = 2 \times 0.512 \times \frac{10}{111} \times \frac{1000}{200}$$

$$\therefore \quad \Delta T_b = 0.461K$$

Q10. (i) Give reason for the following:

(a) Cold drink bottles are *sealed* at high pressure CO_2

(b) Aquatic species are more comfortable in cold water than in warm water.

(ii) Calculate the amount of KCl which must be added to 100 g of water so that water freezes at - 2.0°C. Assume that KCl undergoes complete dissociation. [Given, K_f for water 1.86 K/m]

Ans. (a) CO_2 is less soluble water, so according to Henry's law to increase its solubility bottles are sealed at high pressure of CO_2

(b) In warm water K_H value of O_2 greater than cold water, consequently solubility of O_2 in water increases with decrease of temperature. Hence aquatic species are more comfortable in cold water rather than in warm water.

(ii) $KCl \rightarrow K^+ + Cl^-$

van't Hoff factor (i) = $\frac{2}{1} = 2$

According to formula $\Delta T_f = iK_f\, m \Rightarrow 2 = 2 \times 1.86 \times m$

$$\therefore \quad m = \frac{1}{1.86} = 0.538\ m$$

Amount of KCl dissolved in 100g $= \frac{0.538}{1000} \times 100 \times 74.5 = 4.0008g$

$\therefore$ [Molar mass of KCl = 74.5 g mol^{-1}]

CASE STUDY BASED QUESTION

1. **Read the passage given below and answer the qu est ions that follow:**

Dissolution of solids in water can be accompanied by absorption or evolution of heat i.e. dissolution process may be exothermic or endothermic in nature but dissolution of gases in water is an exothermic process. Dissolution of a substance in water is either due to ion dipole interaction or by hydrogen bond formation.

Dissolution of gases in water is highly affected by pressure. The quantitative relationship between the solubility of gas in liquid and pressure is given by Henry's law in the form of mathematical relationship $p=K_H\chi_B$.

(A) **Dissolution of glucose in water can be explained by:**

(a) Hydrogen bond (b) ion-ion interaction

(c) vander Waals' force (d) ion- dipole interaction

(B) **Solubility of KCl in water increases with the rise in temperature. This means that enthalpy of dissolution of KCl in water:**

(a) $=0$ (b) <0

(c) >0 (d) unpredictable

(C) **The value of K_H for N_2 gas in water at 298K is 86.76k bar, the value of K_H for N_2 in water at 303K in kbar is :**

(a 86.76 (b) >86.7 6

(c) <86.76 (d) unpredictable

2. **Read the passage given below and answer the questions that follow:**

Many biological processes depend on osmosis, which is a spontaneous process by which the solvent molecules pass through a semi permeable membrane from a solution of lower concentration to a solution of higher concentration. The name osmosis is derived from the Greek word 'osmosis' which means 'to push'. It is also important to know that the semipermeable membrance selectivity allows certain molecules in the solution to pass through it but not others. Two solutions having same osmotic pressure at a given temperature are called isotonic solutions. When such solutions are separated by a semipermeable membrane, solvent flow between one to the other one in either direction is same, i.e. the net solvent flow between the two isotonic solution is zero.

In the following questions a statement of assertion followed by a statement or 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 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.

(A) **ASSERTION:** Among all the colligative properties, osmotic pressure measurement provides better method for determination of the molecular mass of the solute.

REASON: Osmotic pressure measurement cannot be carried at room temperature.

(B) **ASSERTION**: The osmotic pressure of 0.1 M urea solution is less than 0.1 M NaCl solution.

REASON : Osmotic pressure is not a colligative property.

(C) **ASSERTION** : The molecular mass of polymers cannot be calculated using the boiling point or freezing point method.

REASON : The boiling point method for determining the molecular mass is used for compounds stable at high temperature.

(D) **ASSERTION** : The elevation in boiling point for two isotonic solutions is same.

REASON : The boiling point depends upon concentration of solute.

3. **Read the passage given below and answer the questions that follow:**

The colligative property of a solution is a property that depends only on the number of solute particles present, not on their identity. An ideal solution is a solution in which all components obey Raoult's law (i.e., $P_A=x_AP^0_A$) throughout the composition range. The vapour pressure of a binary volatile mixture is $P=P^0_B+(P^0_A - P^0_B)\chi_A$. The composition of the vapour is given by $Y_A = x_AP_A^0 / P_B^0+(P_A^0- P_B^0)x_A$ and $Y_B=1-Y_A$. The total vapour pressure of a mixture is $P=P_A^0P_B^0/P_A^0+(P_B^0-P_A^0)Y_A$. Azeotrope is a mixture that boils without change in composition. In colligative properties, the elevation of boiling point is given by $\Delta T_b = k_bm$ and the depression of freezing point by $\Delta T_f=k_fm$. During dissociation of ionic electrolytes, the van't Hoff factor equals, $i= 1+(n-1)\alpha$.

During association of electrolytes, $i=1-\beta+\beta/n$

Here α and β are the degrees of dissociation and association, respectively, of electrolytes.

(A) **The vapour-phase compositions in two binary liquid mixtures follow:**

(a) Boyle's law (b) Dalton's law

(c) Raoult's law (d) Henry's law

(B) **The mole fraction of a solute is 0.4. The relative lowering of vapour pressure is :**

(a) 60% (b) 80%

(c) 40% (d) 20%

(C) **Which is not a colligative property?**

(a) Elevation in boiling point (b) Boiling point

(c) Depression in freezing point (d) Osmotic pressure

(D) **The most accurate method for the measurement of molar mass is:**

(a) osmotic pressure (b) ebullioscopy

(c) cryoscopy (d) Raoult's law

ANSWERS

I **MULTIPLE CHOICE QUESTIONS**

1.	(b)	2.	(a)	3.	(d)	4.	(d)	5.	(d)	6.	(a)	7.	(c)
8.	(c)	9.	(a)	10.	(a)	11.	(c)	12.	(c)	13.	(b)	14.	(a)
15.	(c)	16.	(d)	17.	(c)	18.	(d)	19.	(c)	20.	(d)	21	(c)
22	(a)	23.	(c)	24.	(a)	25.	(c)	26.	(a)	27.	(c)	28.	(d)
29.	(b)												

II **FILL IN THE BLANKS**

1. One 2. Azeotropic mixture 3. Reverse osmosis
4. Solute 5. Increase 6. Greater than
7. van' t Hoff factor 8. Osmotic pressure 9. Edema
10 Association

III **ASSERTION REASON TYPE QUESTIONS**

1. (a) 2. (a) 3. (d) 4. (c) 5. (a) 6. (d)
7. (a) 8. (a) 9. (a) 10. (d) 11. (a)

IV **ONE WORD ANSWER TYPE QUESTIONS**

1. Mole fraction 2. X 3. 0_2
4. Molal elevation constant 5. K kg mol^{-1} 6. Positive deviation
7. Greater 8. Henry's law 9. Molality
10. Positive 11. One 12. Negative deviation1
13. Anoxia 14. Desalination of sea water
15. Association

CASE STUDY BASED QUESTIONS:

1. (A) a (B) b (C) b
2. (A) c (B) c (C) a (D) c
3. (A) c (B) c (C) b (D) a

UNIT TEST - 1
CHAPTER-2
SOLUTIONS

TIME ALLOWED:1 HR. **M.M. 20**

1. 250g fluoride is present in 1000 kg toothpaste sample, concentration of fluoride in ppm is 1

   (a) 250 ppm (b) 25 ppm

   (c) 2500 ppm (d) 4 ppm

2. At a given temperature, the osmotic pressure of a concentrated solution of a substance 1

   (a) is higher than that of a dilute solution.

   (b) is lower that of a dilute solution

   (c) is same as that of a dilute solution

   (d) cannot be compared with osmotic pressure of dilute solution.

3. The value of Henry's law constant K_H is: 1

   (a) Greater for gases with higher solubility

   (b) greater for gases with lower solubility

   (c) constant for all gases

   (d) not related with the solubility of gases

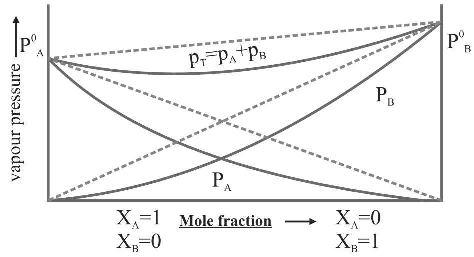
4. What type of deviation from Raoult's law is shown by the liquid mixture forming minimum boiling azeotrope? 1

5. Justify that relative lowering in vapour pressure is a colligative property. 1

6. Draw the graph between vapour pressure and temperature and explain the elevation in boiling point of a solvent in solution. 2

7. CCl_4 and water are immiscible whereas ethanol and water are miscible in all proportions. Explain . 2

8. The graphical representation of vapour pressures of two component system as a function of composition is given below. On the basis of graph answer the questions that follow: 3



(i) Are the A-B interactions weaker, stronger or of the same magnitude as A-A and B-B?

(ii) Name the type of deviation from Raoult's law exhibited by this solution.

(iii) Predict the sign of $\Delta_{mix}H$ for this system.

(iv) Predict the sign of $\Delta_{mix}V$ for this solution.

(v) Give one example of such a solution.

(vi) What type of azeotrope will this system form?

9. A solution containing 1.9g per 100 mL of KCl (molar mass=74.5 $gmol^{-1}$) is isotonic with a solution containing 3g per 100 mL of urea (molar mass=60$gmol^{-1}$). Calculate the degree of dissociation of KCl solution. Assume that both the solutions have same temperature. 3

10. (i) Boiling point is not a colligative property but elevation in boiling point is a colligative property. Comment. 5

(ii) What happens when we place the red blood cell in distilled water?

(iii) State Raoult's law for a solution containing non-volatile solute.

(iv) Define Cryoscopic constant.

UNIT TEST -2
CHAPTER-2
SOLUTION

TIME ALLOWED:1 HR. **M.M. 20**

1. Which of the following is a dimensionless quantity: molarity, molality or mole fraction? (1)
2. N_2 and O_2 gases have K_H values 76.48 kbar and 34.86 kbar respectively at 293 K temperature. Which one of these will have more solubility in water? (1)
3. Liquid 'Y' has higher vapour pressure than liquid 'X'. Which of them will have higher boiling point? (1)
4. Mention the unit of ebulioscopic constant (molal elevation constant). (1)
5. What is the maximum value of van't Hoff factor *(i)* for $Na_2SO_4.10H_20$? (1)
6. Define the term osmosis and osmotic pressure. What is the advantage of using osmotic pressure as compared to other colligative properties for the determination of molar masses of solutes in solutions? (2)
7. Account for the following: (2)
   (a) Aquatic species are more comfortable in winter than summer.
   (b) Solution of acetone and $CHCl_3$ is not an ideal solution.
8. Define isotonic solutions. A 5% solution of cane sugar (Molar mass = 342 g mol^{-1}) is isotonic with 0.887% solution of urea. Find the molar mass of urea. (3)
9. A solution containing 8 g of a substance in 100 g of diethyl ether boils at 36.86°C, whereas pure ether boils at 35.6°C. Determine the molar mass of the] solute. [For diethyl ether K_b = 2.02 K kg mol^{-1}] (3)
10. (a) How will you determine the molecular mass from the relative lowering of vapour pressure?
    (b) At 298 K, the vapour pressure of water is 23.75 mm Hg. Calculate the vapour pressure at the same temperature over 5% aqueous solution of urea NH_2CONH_2. (5)