SOLUTIONS

KEY CONCEPTS

SOLUTION is the homogeneous mixture of two or more than two components. Most of the solutions are binary i.e. consists of two components out of which that is present in the largest quantity called solvent & one which is present in smaller quantity called solute.

EXPRESSING CONCENTRATIONS OF SOLUTIONS

- Mass percentage: Mass of solute per 100g of solution. Mass%= (mass of solute/total mass solution) x 100
- Volume percentage: volume of solute per 100 mL of solutions.
- Parts per million: parts of a component per million (10^6) parts of the solution.
- Mole fraction(x): It is the ratio of no. of moles of one component to the total no. of moles of all the components present in the solution.
- Molarity: No. of moles of solute dissolved in one litre of solution.
- Molality(m): No. of moles of solute per kg of the solvent.
- Molality is independent of temp. whereas molarity is a function of temp. because vol. depends on temp. and mass does not.

HENRY'S LAW

It states that at a constant temp. the solubility of the gas in liquid is directly proportional to the pressure of the gas above the surface of the liquid.

It also states that the partial pressure (p) of a gas in vapour phase is proportional to the mole fraction of the gas (x) in the solution.

$$P=K_HX$$

K_H is Henry's law constant.

APPLICATION OF HENRY'S LAW

- To increase the solubility of CO_2 in soda water and soft drinks the bottle is sealed under high pressure.
- 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.

RAOULT'S LAW:- It states that:

1) For a solution of volatile liquid, the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution.

$$P_A = P^0_A X_A; \quad P_B = P^0_B X_B$$

The total pressure is equal to sum of partial pressure.

$$P_{total}=P_A+P_B$$

2) For a solution containing non-volatile solute the vapour pressure of the solution is directly proportional to the mole fraction of the solvent.

$P_A \alpha X_A \quad P_A = P^0_A X_A$

IDEAL SOLUTION

The solution which obeys Raoult's law over the entire range of concentration when enthalpy of mixing and vol. of mixing of pure component to form solution is zero.

CONDITIONS

I. $P_A = P^0_A X_A \qquad P_B = P^0_B X_B \qquad$ II $\Delta Hmix = 0 \qquad$ III $\Delta Vmix = 0$

This is only possible if A-B interaction is nearly equal to those between A-A and B-B interactions.

Ex:- solution of n-hexane and n-heptane.

NON IDEAL SOLUTION

The solution which do not obey Raoult's law over the entire range of concentrations.

CONDITIONS

I. $P_A \neq P^0_A X_A \qquad P_B \neq P^0_B X_B \qquad$ II $\Delta Hmix \neq 0 \qquad$ III $\Delta Vmix \neq 0$

The vapour pressure of such solutions is either higher or lower than that predicted for Raoult's law.

I. If vapour pressure is higher, the solutions shows positive deviation (A-B interaction are weaker than those between A-A and B-B).

Ex: mixture of ethanol and acetone.

$P_A > P^0_A X_A \; ; \quad P_B > P^0_B X_B$

$\Delta Hmix =$ Positive, $\Delta Vmix =$ Positive

II. If vapour pressure is lower, the solution shows negative deviation (A-B interaction are stronger than those between A-A and B-B).

Ex: mixture of chloroform and acetone.

$P_A < P^0_A X_A \qquad P_B < P^0_B X_B$

$\Delta Hmix =$ negative, $\Delta Vmix =$ negative

AZEOTROPE

Mixture of liquid having the same composition in liquid and vapour phase and boil at constant temp.

Azeotrope are of two types:-

a) Minimum boiling azeotrope :- The solution which shows a large positive deviation from Raoult's law. ex- ethanol-water mixture.

b) Maximum boiling azeotrope :- the solution which shows large negative deviation from Raoult's law. Ex- nitric acid-water mixture.

COLLIGATIVE PROPERTIES Properties of ideal solution which depends upon no. of particles of solute but independent of the nature of the particles are called colligative properties.

1. RELATIVE LOWERING OF VAPOUR PRESSURE

$(P^O_A - Ps)/P^O_A = X_B, \qquad X_B = n_B / n_A + n_B$

For dilute solution, $n_B << n_A$, hence n_B is neglected in the denominator. $(P^O_A - Ps)/P^O_A = n_B / n_A \quad (P^O_A - Ps)/P^O_A$

$= W_B \times M_A / M_B \times W_A$

2. ELEVATION OF BOILING POINT

$\Delta T_b = k_b m$ Where $\Delta T_b = T_b - T^O_b$

k_b = molal elevation constant/ Ebullioscopic constant m=molality

$M_B = k_b \times 1000 \times W_B / \Delta T_b \times W_A$

3. DEPRESSION IN FREEZING POINT

$\Delta T_f = k_f m$ Where $\Delta T_f = T^O_f - T_f$

K f= molal depression constant/ Cryoscopic constant m=molality

$M_B = k_f \times 1000 \times W_B / \Delta T_f \times W_A$

4. OSMOTIC PRESSURE

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.

$\pi = CRT$

$\pi = n_B/VRT$ (n_B =no.of moles of solute; V= volume of solution(L) R= 0.0821Latmmol^{-1}; T= temperature in kelvin

ISOTONIC SOLUTION

Two solutions having same osmotic pressure and same concentration.

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 blood cell.

VAN'T HOFF FACTOR (i)

Ratio of normal molecular mass to the observed molecular mass of the solute.

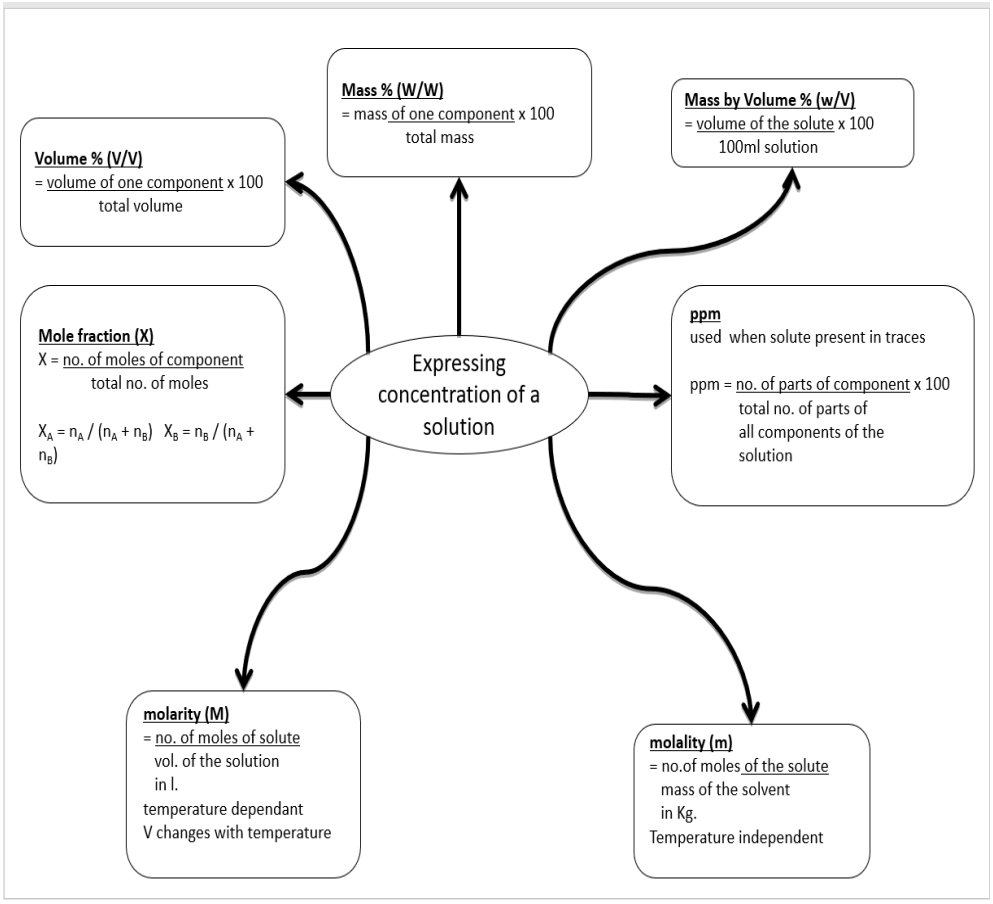
i = normal molecular mass/ observed molecular mass

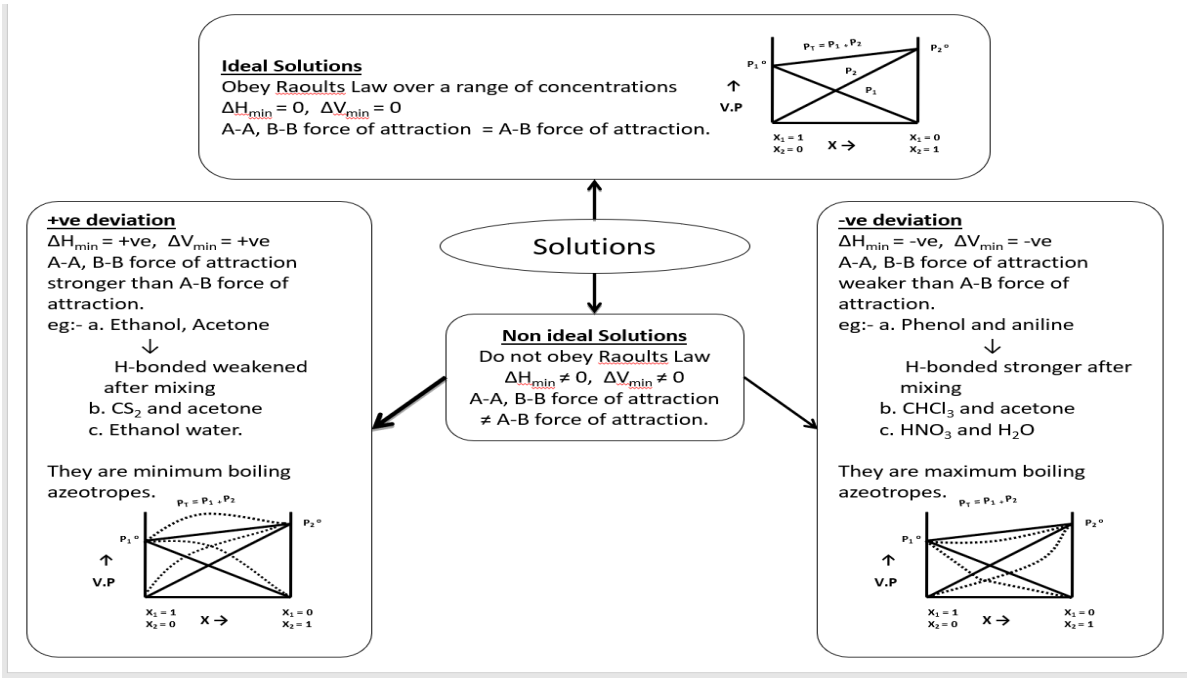
= observed colligative properties/ calculated value of colligative properties i<l

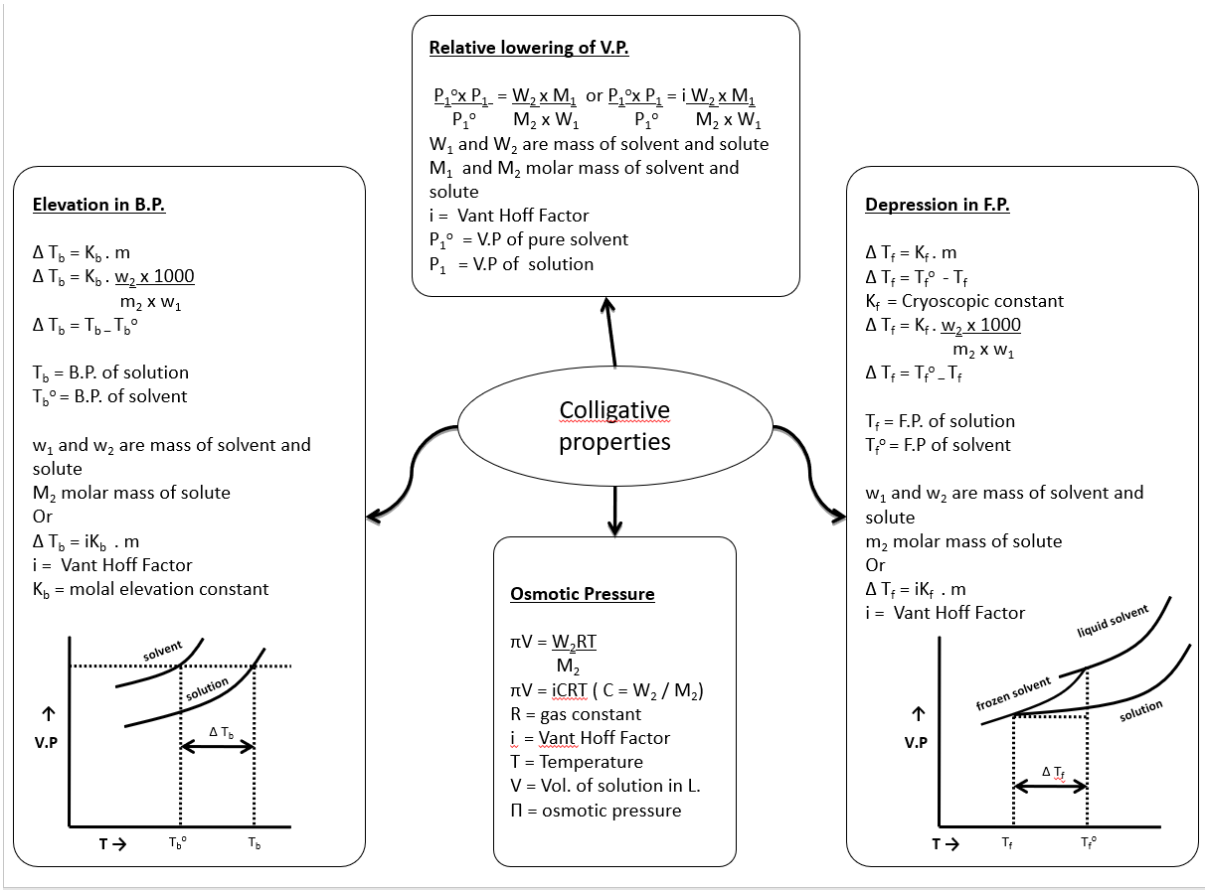
(for association) i>l (for dissociation)

MODIFIED FORMS OF COLLIGATIVE PROPERTIES

1) $(P^O_A - Ps)/P^O_A = i x X_B$ 2) $\Delta_{Tb} = i \times k_b m$ 3) $\Delta T_f = ix\ k_f m$ 4) $\pi = ix\ CRT$


Expressing concentration of a solution
Mass % (W/W)
= mass of one component x 100
total mass
Mass by Volume % (w/V)
= volume of the solute x 100
100ml solution
Volume % (V/V)
= volume of one component x 100
total volume
Mole fraction (X)
X = no. of moles of component
total no. of moles
$X_A = n_A / (n_A + n_B)$ $X_B = n_B / (n_A + n_B)$
ppm
used when solute present in traces
ppm = no. of parts of component x 100
total no. of parts of
all components of the
solution
molarity (M)
= no. of moles of solute
vol. of the solution
in l.
temperature dependant
V changes with temperature
molality (m)
= no.of moles of the solute
mass of the solvent
in Kg.
Temperature independent


Solutions
Ideal Solutions
Obey Raoults Law over a range of concentrations
$\Delta H_{min} = 0$, $\Delta V_{min} = 0$
A-A, B-B force of attraction = A-B force of attraction.
V.P
X →
Non ideal Solutions
Do not obey Raoults Law
$\Delta H_{min} \neq 0$, $\Delta V_{min} \neq 0$
A-A, B-B force of attraction
≠ A-B force of attraction.
+ve deviation
ΔH_{min} = +ve, ΔV_{min} = +ve
A-A, B-B force of attraction stronger than A-B force of attraction.
eg:- a. Ethanol, Acetone
↓
H-bonded weakened after mixing
b. CS_2 and acetone
c. Ethanol water.
They are minimum boiling azeotropes.
-ve deviation
ΔH_{min} = -ve, ΔV_{min} = -ve
A-A, B-B force of attraction weaker than A-B force of attraction.
eg:- a. Phenol and aniline
↓
H-bonded stronger after mixing
b. $CHCl_3$ and acetone
c. HNO_3 and H_2O
They are maximum boiling azeotropes.



Multiple Choice Questions

1. Low concentration of oxygen in the blood and tissues of people living at high altitude is due to
   (a) low temperature (b) low atmospheric pressure
   (c) high atmospheric pressure (d) both low temperature and high atmospheric pressure
2. 3 moles of P and 2 moles of Q are mixed, what will be their total vapour pressure in the solution if their partial vapour pressures in pure state are 80 and 60 torr respectively?
   (a) 80 torr (b) 140 torr (c) 72 torr (d) 70 torr
3. Considering the formation, breaking and strength of hydrogen bond, predict which of the following mixtures will show a positive deviation from Raoult's law?
   (a) Phenol and aniline (b) Chloroform and acetone
   (c) Nitric acid and water (d) Methanol and acetone
4. Colligative properties depend on
   (a) the nature of the solute (b) the number of solute particles in solution
   (c) the physical properties of solute (d) the nature of the solvent
5. Which of the following aqueous solutions should have the highest boiling point?
   (a) 1.0 M Glucose (b) 1.0 M Na_2SO_4 (c) 1.0 M KCl (d) 1.0 M Urea
6. In comparison to a 0.01 M solution of glucose, the depression in freezing point of a 0.01 M $MgSO_4$ solution is
   (a) the same (b) about twice (c) about three times (d) about six times
7. An unripe mango placed in a concentrated salt solution to prepare pickles shrinks because

(a) it gains water due to osmosis (b) it loses water due to reverse osmosis
(c) it gains water due to reverse osmosis (d) it loses water due to osmosis

8. K_H value 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
9. Sprinkling of salt helps in clearing the snow covered roads in hills. The phenomenon involved in the process is
(a) lowering in vapour pressure of snow
(b) depression in freezing point of snow
(c) melting of ice due to increase in temperature by putting salt
(d) increase in freezing point of snow
10 . What will be the degree of dissociation of 0.1 M $Mg(NO_3)_2$ solution if van't Hoff factor is 2.74?
(a) 75% (b) 87% (c) 100% (d) 92%

ASSERTION& REASON TYPE QUESTIONS

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

i. **Assertion and reason both are correct statements and reason is correct explanation for assertion.**
ii. **Assertion and reason both are correct statements but reason is not correct explanation for assertion.**
iii. **Assertion is correct statement but reason is wrong statement.**
iv. **Assertion and reason both are incorrect statements.**

1. **Assertion (A) :** 0.1 M solution of KCl has greater osmotic pressure than 0.1 M solution of glucose at same temperature.
Reason (R) : In solution, KCl dissociates to produce more number of particles.
2. **Assertion:** If on mixing the two liquids, the solution becomes hot, it implies that it shows negative deviation from Roult's law.
Reason(R): Solution which shows negative deviation from Roult's law are accompanied by decrease in volume.
3. **Assertion (A) :** An ideal solution obeys Henry's law.
Reason (R) : In an ideal solution, solute-solute as well as solvent solvent interactions are different from solute-solvent interaction.
4. **Assertion(A):** When a solution is separated from the pure solvent by a semi-permeable membrane, the solvent molecules pass through it from pure solvent side to the solution side.
Reason(R): Diffusion of solvent occurs from a region of high concentration solution to a region of low concentration solution.
5. **Assertion(A):** Azeotropic mixtures are formed only by non-ideal solutions and they may have boiling points either greater than or less than both the components.
Reason(R): The composition of the vapour phase is same as that of liquid phase of the azeotropic mixture.

2 - MARK QUESTIONS

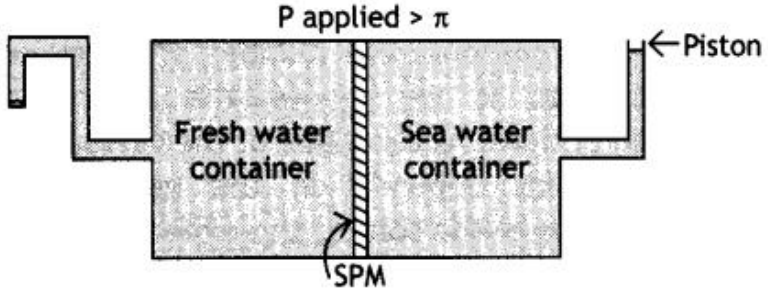
1. Vapour pressure of two liquid A & B are 120 and 180mm Hg at a given temp. If 2 mole of A and 3 mol of B are mixed to form an ideal solution, calculate the vapour pressure of solution at same temperature.
2. 18 g of glucose, $C_6H_{12}O_6$ (Molar mass = 180 g mol^{-1}) is dissolved in 1 Kg of water in a sauce pan. At what temperature will this solution boil?
3. (a) Why is the freezing point depression of 0.1M NaCl solution nearly twice that of 0.1M glucose solution?
   (b) What is the effect of temperature on Henry's law constant (K_H) and on solubility of a gas on liquid?
4. 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?
5. (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?

3 - MARKS QUESTIONS

1. 3.9 g of benzoic acid dissolved in 49 g of benzene shows a depression in freezing point of 1.62 K. Calculate the van't Hoff factor and predict the nature of solute (associated or dissociated). (Given: Molar mass of benzoic acid = 122 g mol^{-1}, K_f for benzene = 4.9 K kg mol^{-1})
2. A solution is made by dissolving 30 g of non-volatile solute in 90 g of water. It has a vapour pressure of 2.8 kPa at 298 K. At 298 K, vapour pressure of pure water is 3.64 kPa. Calculate the molar mass of the solute.
3. Answer the following questions:
   (a) Why is 1 molar aqueous solution more conc. than a 1 molal solution?
   (b) Which out of molarity and molality will change with temperature and why?
   (c) Will the molarity of a solution at 50^0C be same, less or more than molarity at 25^0C ?
4. On dissolving 3.24 g of sulphur in 40 g of benzene, boiling point of solution was higher than that of benzene by 0.81 K. Kb value for benzene is 2.53 K Kg mol-1. What is the molecular formula of sulphue? (Atomic mass of sulphur = 32 g/mol)
5. Answer
   (a) What happen to vapour pressure of water if a table spoon of salt is added to it?
   (b) Why does the use of pressure cooker reduce the cooking time?
   (c) Two liquid A & B are mixed and the resulting solution is found to be cooler. What do you conclude about deviation of solution from ideal behavior?

6. Given below is the sketch of a plant for carrying out a process.



(a) Name the process occurring in the above plant.
(b) To which container does the net flow of solvent take place?
(c) Give one practical use of the plant.

5 - MARKS QUESTIONS

1. (a) Define the term osmosis and osmotic pressure. Is the osmotic pressure of a solution a colligative property.

Explain.
(b) Calculate the boiling point of a solution prepared by adding 15 g of NaCl to 250 g of water. (Kb for water = 0.512 K Kg mol-1 and molar mass of NaCl = 58.5 g/mol).

2. (a) State the following:
(i) Henry's Law about partial pressure of a gas in a solution.
(ii) Raoult's Law in its general form in reference to solutions.

(b) 0.004 M soln of Na_2SO_4 is isotonic with 0.01 M soln of glucose at the temp. What is the apparent degree of dissociation of Na_2SO_4 ?

CASE BASED QUESTIONS

Q1. A raw mango placed in concentrated salt solution loses water via osmosis and shrivel into pickle. Wilted flowers revive when placed in fresh water. A carrot that has become limp because of water loss into the atmosphere can be placed into the water making it firm once again. Water will move into its cells through osmosis. When placed in water containing less than 0.9% (mass/ volume) salt, blood cells swell due to flow of water in them by osmosis.

(a) People taking a lot of salt or salty food suffer from puffiness or edema. What is the reason behind this?

(b) The preservation of meat by salting and of fruits by adding sugar protects against bacterial action. How?

(c) Why the direction of osmosis gets reversed if a pressure larger than the osmotic pressure is applied to the solution side? Write its one application.

OR

(c) What care is generally taken during intravenous injections and why?

Q2. In order to overcome the scarcity of drinking water in a remote village in Gujarat, Arnav and Aariv two young entrepreneurs still in their high school, have developed a unique water purifier that is capable of converting sea water into drinking water. It works on the principle of concentration difference between two solutions. Based on your understanding of solutions answer the following questions about the product made by Arnav & Aariv:
(a)Name the phenomenon/ process based on which this product is made?
(b)How difference in concentration of solutions help in converting sea water into drinking water?
(c)What arrangement they must have created in their product to covert sea water into drinking water?

OR

(c)Equimolar solutions of NaCl and glucose are not isotonic. Why?

Q3. Aariv Sharma is very fond of a special drink made by his grandmother using different fruits available in their hometown. It has an outstanding taste and also provide great health benefits of natural fruits. He thought of utilizing his grandmother recipe to create a new product in the beverage market that provide health benefits and also contain fizziness of various soft drinks available in the market. Based on your understanding of solutions chapter, help Aariv Sharma to accomplish his idea by answering following:

(a) How he can add fizz to the special drink made by his grandmother?
(b) What is the law stated in the chapter that can help Aariv to make his drink fizzy?
(c) What precautions he should take while bottling so that his product does not lose fizz during storage and handling across long distances? OR

(c)The mole fraction of helium in a saturated solution at 20°C is 1.2 x 10-6. Find the pressure of helium above the solution. Given Henry's constant at 20°C is 144.97 kbar.

ANSWERS

MCQ 1(b); 2(c); 3(a); 4(b); 5(b);6(b);7(d);8(c);9(b);10(b)

ASSERTION REASON: 1(i); 2(ii); 3(iv); 4(iii); 5(ii)

2-MARKS

1. Total moles = 2 + 3 = 5

P solution = $P_A^\circ \, x_A + P_B^\circ \, x_B$

$= \frac{2}{5} \times 120 + \frac{3}{5} \times 180$ = 48 + 108 = 156mm.

2. w_1 = weight for solvent (H_2O) = 1 Kg
w_2 = weight of solute glucose = 18 g
M_2 = molar mass of solute, glucose = 180 g mol^{-1}
K_b = 0.52 K Kg mol^{-1}

$$T_b^0 = 373.15K$$

$$\Delta T_b = \frac{K_b \times 1000 \times w_2}{M_2 \times w_2} = 0.052 \text{ K}$$

$$\Delta T_b = T_b - T_b^0 \Rightarrow 0.052 = T_b - 373.15 \Rightarrow T_b = 373.202 \, K$$

3. (a) NaCl is an electrolyte and dissociates completely whereas glucose being a non-electrolyte does not dissociate.Hence, the number of particles in 0.1M NaCl solution is nearly double than that in 0.1M glucose solution.Depression in freezing point being a colligative property is nearly twice for NaCl solution than for glucose solution of same molarity.
(b) Solubility of a gas in liquid decreases with increase in temperature. K_H value increases with the increase in temperature.

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

(i) Osmotic pressure is measured at the room temperature and the molarity of solution is used instead of molality.
(ii) Compared to other colligative properties, its magnitude is large even for very dilute solutions.

5.(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.

3-MARKS QUESTIONS

1. $\Delta T_f = i \, K_f \times m$
$= i \times K_f \times W_2 \times 1000 / M_2 \times W_1$
W_2 = 3.9 g, W_1 = 49 g, ΔT_f = 1.62 K,
M_2 = 122 g mol^{-1}
K_f = 4.9 K kg mol^{-1}
$1.62 = i \times 4.9 \times 3.9 \times 1000122 \times 49$
or $i = 1.62 \times 122 \times 494.9 \times 3.9 \times 1000 = 0.506$
Since i is less than 1, the solute is associated.

2. $(P_0\text{-}Ps)/P_0 = \frac{WB/MB}{\frac{WB}{MB} + \frac{WB}{MA}}$

M_B = 20 g /mol

3. (a)A molar solution contains one mole of solute in one litre of solution while a one molal solution contains one mole of solute in 1000 g of solvent. If density of water is 1, then one mole of solute is present in 1000 ml of water in one molar solution while on mole of solute is present in less than 1000 ml of water in one molar solutions. Thus, one molar solution is more concentrated.
   (b)Molarity changes with rise in temperature. Volume of a solution increases with rise in temperature and this causes change in molarity because it is related as moles of solute in a given volume of solution.
   (c) Molarity at 50^0C of a solution will be less than that of 25^0C because morality decreases with temperature. This is because volume of the solution increases with increase in temperature but number of moles of solute remains the same.
4. $M_B = \frac{Kbx\ WBx1000}{\Delta Tbx\ WA}$
   $= \frac{2.53x\ 3.24x\ 1000}{0.81\ x\ 40}$
   = 253g/mol
   No. of atoms in one molecule of sulphur = 253/32 = 7.8 = 8
   So molecular formula of sulphur is S_8.
5. (a) Addition of non volatile solute lower the vapour pressure of solvent(water)
   (b)At higher pressure over the liquid, the liquid boils at high temperature. Therefore, cooking occur fast.
   (c)Positive deviation.
6. (a) Reverse osmosis
   (b) To fresh water container
   (c) This can be used as a desalination plant to meet potable water requirements.

5 - MARKS QUESTIONS

1. (a) Net flow of solvent molecules from the pure solvent to the solution through semi permeable membrane is called osmosis.
The extra pressure that applied from solution side to prevent the flow of solvent through SPM is called osmotic pressure.
Osmotic pressure is a colligative property because it depends upon no. of moles of solute.

(b) $\Delta Tb = \frac{i\ x\ Kb\ x\ WB\ x\ 1000}{MB\ x\ WA}$

$= \frac{2\ x\ 0.512\ x\ 15\ x\ 1000}{58.5\ x\ 250}$

= 1.052 K

Boiling point of the solution = 373 + 1.052 = 374.052 K

2.(a) (i) The partial pressure of a gas, p in vapour phase is proportional to the mole fraction of the gas in solution.

(ii) In a solution, the partial pressure of each volatile component is directly proportional to its mole fraction in the solution.

(b) For isotonic solutions,

$\pi (Na_2SO_4) = \pi$ (glucose)

$\pi (Na_2SO_4) = i \times C \times R \times T = i \times 0.004 \times RT$

π (glucose) = i x C x R x T = 1 x 0.01 x RT

i x 0.004 x RT = 1 x 0.01 x RT

i = 2.5

$\alpha = i - 1/n - 1 = 2.5 - 1/ 3 - 1 = 0.75$

Degree of dissociation is 75%.

CASE BASED QUESTIONS

1. (a) People experience water retention in tissue cells and intercellular spaces due to osmosis.
(b) Through the process of osmosis, a bacterium on salted meat or candid fruit loses water, shrivels and dies.

(c) The pure solvent flows out of the solution through the semi permeable membrane due to reverse osmosis. It is used in desalination of sea water.

OR

(c) During intravenous injection, the concentration of the solution should be same as that of blood so that they are isotonic. Because if the solution concentration is hypertonic than blood cell will shrink and if it is hypotonic than blood cell will swells / burst.

2. a) The product is based on the phenomenon of Reverse Osmosis between solutions of two different concentration.
b) When solutions of two different concentration are separated by a semipermeable membrane and excess pressure is applied on the solution of higher concentration, solvent flow from higher concentration to lower concentration. This is called Reverse Osmosis and same can be used to treat seawater and convert into drinking water.
c) Following arrangement must have been made:
i) Use of a semipermeable membrane.
ii) Separate Compartment having seawater and Drinking Water separated by semipermeable membrane.
iii) Excess pressure applied in compartment having sea water.

OR

(c) NaCl is an electrolyte and gets dissociated to two ions (Na^+ and Cl^-) and exerts almost double osmotic pressure than glucose which is a non-electrolyte and does not dissociate.

3. (a) Carbondioxide is a gas which provide fizz and tangy flavour. He can dissolve Carbondioxide gas in the drink.
(b) Henry's law which states that solubility of a gas in liquid is directly proportional to partial pressure of the gas.
(c) Bottles should be sealed under high pressure of CO_2 and capping should be done perfectly to avoid leakage of CO_2 as any loss of partial pressure will result into decrease in solubility.

OR

(c) $p_{He} = K_H \times X_{He}$
$= (144.97 \times 10^{3} bar)(1.2 \times 10^{-6}$
$= 0.174$ bar