CACE STUDY BASED QUESTIONS
CH. 2
SOLUTIONS

1. Colligative properties are properties of solution which depend on the number of solute particles in the solution irrespective of their nature.
   a) Name the four important colligative properties. (2)
   b) What happens to the colligative properties when ethanoic acid is treated with benzene? Give reason. (2) [MARCH 2010]

   Ans: a) The important colligative properties are Relative lowering of vapour pressure, Elevation of boiling point, Depression of freezing point, Osmotic pressure.

   b) Ethanoic acid (acetic acid) dimerises in benzene. So the no. of particles decreases and hence the colligative properties decreases.

2. Relative lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure are important colligative properties of dilute solutions.
   a) Relative lowering of vapour pressure of an aqueous dilute solution of glucose is 0.018. What is the mole fraction of glucose in the solution? (1)
   b) An aqueous dilute solution of a non-volatile solute boils at 373.052K. Find the freezing point of the solution. For water K_b = 0.52 K kgmol^{-1} and K_f = 1.86 K kgmol^{-1}. Normal boiling point of water = 373K and normal freezing point = 273K. (3) [SAY 2011]

   Ans: a) Relative lowering of Vapour pressure $(\Delta P/ P_1^0) = x_2$, the mole fraction of the solute.

   Here relative lowering of vapour pressure of glucose = 0.018. So its mole fraction = 0.018.

   b) Here b.p of solution (T_b) = 373.052 K *and that of water* (T_b^0) = 373 K.

   Elevation of b.p, $\Delta T_b = T_b - T_b^0$ = 373.052 -373 = 0.052 K

   We know that, $\Delta T_b = K_b.m$

   So, molality, $m = \Delta T_b / K_b$ = 0.052/0.52 = 0.1

   The depression in freezing point, $\Delta T_f = K_f.\ m$ = 1.86 x 0.1 = 0.186 K

   Also, $\Delta T_f = T_f - T_f^0$

   So, freezing point of the solution $(T_f) = \Delta T_f + T_f^0$ = 0.186 + 273 = 273.186 K

3. Colligative properties can be used to determine the molar mass of solutes in solutions.
   a) What do you mean by colligative properties? (1)
   b) For determining the molecular mass of polymers, osmotic pressure is preferred to other properties. Why? (1)
   c) For intravenous injections only solutions with osmotic pressure equal to that of 0.9% NaCl solution is used. Why? (2) [MARCH 2011]

   Ans: a) These are properties which depend on the number of solute particles and not on their nature.

   b) Polymers have poor solubility and so their solution is very dilute. The magnitude of osmotic pressure is large even for very dilute solutions. So osmotic pressure measurement is used for the determination of their molar mass.

   c) This is because our blood cells are isotonic with 0.9% (mass/volume) NaCl solution. So osmosis does not occur if we place the blood cells in this solution. (If the blood cells are placed in NaCl solution with higher or lower concentrations than 0.9 %, they would shrink or swell).

4. Vapour pressure of a solution is different from that of pure solvent.
   i) Name the law which helps us to determine partial vapour pressure of a volatile component in a solution. (½)
   ii) State the above law. (1)

iii) Vapour pressure of chloroform ($CHCl_3$) and dichloromethane (CH_2Cl_2) at 298K are 200 mm of Hg and 415 mm of Hg respectively. Calculate the vapour pressure of solution prepared by mixing 24g of chloroform and 17g of dichloromethane at 298K. (2½) [MARCH 2012]

Ans: i) Raoult's law

ii) The law states that for a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction present in solution.

iii) Let $CHCl_3$ be the component 1 and CH_2Cl_2 be the component 2.

Then vapour pressure of pure chloroform (P_1^0) = 200 mm of Hg and vapour pressure of pure CH_2Cl_2 (P_2^0) = 415 mm of Hg.

Mass of Chloroform (w_1) = 24 g

Molar mass of Chloroform, $CHCl_3$ (M_1) = 12 + 1 + 3 x 35.5 = 119.5 g/mol

No. of moles of Chloroform (n_1) = w_1/M_1 = 24/119.5 = 0.2 mol

Mass of dichloromethane (w_2) = 17 g

Molar mass of dichloromethane, CH_2Cl_2 (M_2) = 12 + 2 x 1 + 2 x 35.5 = 85 g/mol

No. of moles of CH_2Cl_2 (n_2) = w_2/M_2 = 17/85 = 0.2 mol

Mole fraction of CH_2Cl_2 (x_2) = $n_2/(n_1+n_2)$ = 0.2/(0.2+0.2) = 0.5

Total pressure of the solution = $P_1^0 + (P_2^0 - P_1^0).x_2$ = 200 + (415-200) x 0.5 = <u>307.5 mm of Hg</u>

[Or, find out x_1 also and then calculate P_1 ($P_1 = P_1^0.x_1$), P_2 ($P_2 = P_2^0.x_2$) & $P_{Total} = P_1 + P_2$]

5. Colligative properties are properties of solution which depend on the number of solute particles in the solution.
   i) Write the names of four important colligative properties. (2)
   ii) The value of van't Hoff factor 'i', for aqueous KCl solution is close to 2, while that for ethanoic acid in benzene is nearly 0.5. Give reason. (2)

Ans: i) Relative lowering of vapour pressure, Elevation of boiling point, Depression of freezing point, Osmotic pressure.

ii) KCl dissociates in aqueous solution. So the no. of solute particles gets doubled and hence 'i' is close to 2. While ethanoic acid dimerises in benzene. So the no. of particles gets halved and hence 'i' is nearly 0.5.

6. Elevation of boiling point is a colligative property.
   i) What are colligative properties? (1)
   ii) Elevation of boiling point (ΔT_b) is directly proportional to molality (m) of solution. Thus $\Delta T_b = K_b.m$, K_b is called molal elevation constant. From the above relation derive an expression to obtain molar mass of the solute.(1)
   iii) The boiling point of benzene is 353.23 K. When 1.80 g of a non-volatile solute was dissolved in 90 g of benzene, the boiling point is raised to 354.11K. Calculate the molar mass of the solute. K_b for benzene is 2.53 K kg mol^{-1}. (1) [MARCH 2013]

Ans: i) These are properties which depend on the number of solute particles and not on their nature.

ii) Given $\Delta T_b = K_b.m$

But molality $m = \dfrac{w_2 \times 1000}{M_2 \times w_1}$

Therefore, $\Delta T_b = \dfrac{K_b. w_2 \times 1000}{M_2.w_1}$

Or, $\Delta T_b = \dfrac{1000 K_b.w_2}{w_1.M_2}$ *Where w_1 = mass of solvent, w_2 = mass of solute, M_2 = molar mass of solute. By using this equation, we can calculate the molar mass of unknown solute.*

iii) We know that $\Delta T_b = \frac{1000\ K_b \cdot w_2}{w_1 \cdot M_2}$

Here $w_2 = 1.80$ g, $w_1 = 90$g, $\Delta T_b = T_b - T_b^0 = 354.11 - 353.23 = 0.88$ K, $K_b = 2.53$ K kg/mol, $M_2 = ?$

On substituting in the above equation, we get

$$0.88 = \frac{1000 \times 2.53 \times 1.80}{90 \times M_2}$$

So, $M_2 = \frac{1000 \times 2.53 \times 1.8}{90 \times 0.88} = \underline{57.5\ g/mol}$

7. Liquid solutions can be classified into ideal and non-ideal solutions on the basis of Raoult's law.
   a) State Raoult's law. (1)
   b) What are ideal solutions? (1)
   c) Write any two properties of ideal solutions. (1)
   d) What type of deviation is shown by a mixture of chloroform and acetone? Give reason. (1)

[SAY 2013]

Ans: a) The law states that for a solution of volatile liquids, the partial vapour pressure of each component in the solution is directly proportional to its mole fraction present in solution.

b) These are solutions which obey Raoult's law at all concentrations.

c) For an ideal solution, $P_1 = P_1^0 x_1$, $P_2 = P_2^0 x_2$, $\Delta H_{mix} = 0$ and $\Delta V_{mix} = 0$

d) Negative deviation. Chloroform can form hydrogen bond with acetone. So the solute – solvent interaction increases and hence the vapour pressure decreases.

8. Osmotic pressure is a colligative property and it is proportional to the molarity of the solution.
   a) What is osmotic pressure? (1)
   b) Molecular mass of NaCl determined by osmotic pressure measurement is found to be half of the actual value. Account for it? (1)
   c) Calculate the osmotic pressure exerted by a solution prepared by dissolving 1.5 g of a polymer of molarmass 185000 in 500ml of water at 37^0C. (R = 0.0821 L atm/K/mol) (2) [March 2014]

Ans: a) It is the excess pressure that must be applied on solution side to stop osmosis. Or, it is the pressure that just stops the flow of solvent molecules through a semi-permeable membrane.

b) This is because NaCl dissociates in aqueous solution. Hence the no. of particles gets doubled and colligative property (osmotic pressure) becomes halved.

c) Here $w_2 = 1.5$ g, R = 0.0821 L atm/K/mol, $M_2 = 185000$, T = 37^0C = 37 + 273 = 310K and V= 500 mL = 0.5 L

We Know that, Osmotic pressure, $\pi = \frac{w_2 RT}{M_2 V} = \frac{1.5 \times 0.0821 \times 310}{185000 \times 0.5} = \underline{4.13 \times 10^{-4}\ atm}$

9. Molarity (M), molality (m) and mole fraction (x) are some methods for expressing concentration of solutions.
   a) Which of these are temperature independent? (1)
   b) Define mole fraction? (1)
   c) A mixture contains 3.2g methanol (molecular mass = 32u) and 4.6g ethanol (molecular mass = 46u). Find the mole fraction of each component. (2) [SAY 2014]

Ans: a) Molality and mole fraction.

b) Mole fraction is the ratio of the number of moles of a particular component to the total number of moles of solution.

c) Let methanol be component 1 and ethanol be component 2.

Then $w_1 = 3.2$ g, $M_1 = 32$ u, $w_2 = 4.6$ g and $M_2 = 46$u.

No. of moles of methanol (n_1) = w_1/M_1 = 3.2/32 = 0.1 mol
No. of moles of ethanol (n_2) = w_2/M_2 = 4.6/46 = 0.1 mol
*Mole fraction of methanol (x_1) = $n_1/(n_1+n_2)$ = 0.1/(0.1+0.1) = **0.5***
*Mole fraction of ethanol (x_2) = 1 – x_1 = 1 – 0.5 = **0.5***

10. a) Among the following, which is not a colligative property?
 i) Osmotic pressure ii) Elevation of boiling point iii) Vapour pressure iv) Depression of freezing point (1)

b) i) 200 cm^3 of aqueous solution of a protein contains 1.26 g of protein. The osmotic pressure of the solution at 300 K is found to be 8.3 x 10^{-2} bar. Calculate the molar mass of protein. (R = 0.083 $LbarK^{-1}mol^{-1}$) (2)

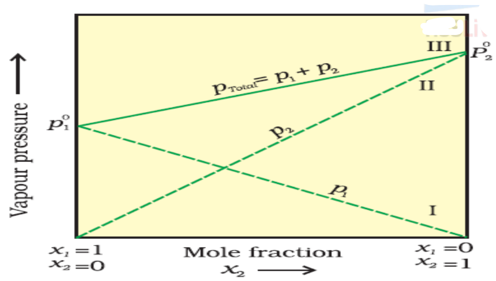
ii) What is the significance of van't Hoff factor? (1) [March 2015]

Ans: a) iii) Vapour pressure
b) i) Here w_2 = 1.26 g, R = 0.083 L bar/K/mol, π = 8.3 x 10^{-2} bar, T = 300K & V= 200 cm^3 = 0.2 L
We Know that, Molar mass of solute, $M_2 = \frac{w_2RT}{\pi V} = \frac{1.26 \times 0.083 \times 300}{8.3 \times 10^{-2} \times 0.2} = \underline{\underline{1890\ g/mol}}$

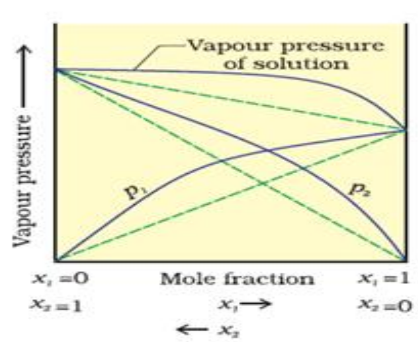
ii) van't Hoff factor is used to correct the abnormal molar mass of solute if there is association or dissociation of particles.

11. a) Draw a vapour pressure curve, by plotting vapour pressure against mole fraction of an ideal solution of two components A and B. indicate partial vapour pressure of A and B (P_A and P_B) and the total vapour pressure (P_{Total}). (2)
b) What is an ideal solution? (1)
c) Modify the above plot for non-ideal solution showing positive deviation. (Draw the above plot once again and modify.) (1) [SAY 2015]

Ans: a)



b) A solution which obeys Raoult's law at all concentrations is called ideal solution.
c)



12. a) Number of moles of the solute per kilogram of the solvent is:
 (a) Mole fraction (b) Molality (c) Molarity (d) Molar mass (1)
 (b) 'The extent to which a solute is dissociated or associated can be expressed by Van't Hoff factor.' Substantiate the statement. (1)

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(c) The vapour pressure of pure benzene at a certain temperature is 0.850 bar. A nonvolatile, non-electrolyte solid weighing 0.5 g when added to 39 g of benzene (molar mass 78 g mol^{-1}), vapour pressure becomes 0.845 bar. What is the molar mass of the solid substance? (2) [March 2016]

Ans: a) Molality

b) van't Hoff factor, $i = \dfrac{\text{Total number of moles of particles after association/dissociation}}{\text{Number of moles of particles before association/dissociation}}$

If the value of i < 1, association occurs and if the value of i > 1, dissociation occurs.

c) We know that, $\dfrac{\Delta P}{P_1^0} = \dfrac{w_2 \times M_1}{w_1 \times M_2}$

Here vapour pressure of pure solvent benzene (P_1^0) *= 0.850 bar, Mass of benzene* (w_1) *= 39 g, mass of solute* (w_2) *= 0.5 g, molar mass of benzene* (M_1) *= 78 g/mol and vapour pressure of solution* (P_1) *= 0.845 bar*

$\Delta P = P_1^0 - P_1 = 0.850 - 0.845 = 0.005$ bar

On substituting in the above equation, we get,

$$\frac{0.005}{0.850} = \frac{0.5 \times 78}{39 \times M_2}$$

So, $M_2 = \dfrac{0.5 \times 78 \times 0.85}{0.005 \times 39} = \underline{\underline{170\ g/mol}}$

13. Osmotic pressure is a colligative property.
    a) What is osmotic pressure? (1)
    b) 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40K. The freezing point depression constant of benzene is 5.12 K kg/mol. Find the molar mass of the solute. (3) [SAY 2016]

Ans: a) It is the excess pressure that must be applied on solution side to prevent osmosis.

b) We know that $\Delta T_f = \dfrac{1000\ K_f .\ w_2}{w_1 .\ M_2}$

Here $w_2 = 1.00$ g, $w_1 = 50$g, $\Delta T_f = 0.40$ K, $K_f = 5.12$ K kg/mol, $M_2 = ?$

On substituting in the above equation, we get

$$0.4 = \frac{1000 \times 5.12 \times 1}{50 \times M_2}$$

So, $M_2 = \dfrac{1000 \times 5.12 \times 1}{50 \times 0.4} = \underline{\underline{256\ g/mol}}$

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14. a) Henry's law is related to solubility of a gas in liquid.
    (i) State Henry's law. (2)
    (ii) Write any two applications of Henry's law. (2)
    b) 1000cm^3 of an aqueous solution of a protein contains 1.26 g of the protein. The osmotic pressure of such a solution at 300K is found to be 2.57 x 10^{-3} bar. Calculate the molar mass of the protein. (R = 0.083 L bar/K/mol). (2) [March 2017]

Ans: a) (i) Henry's law states that at constant temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas.

Or, at constant temperature, the partial pressure of the gas in vapour phase is proportional to the mole fraction of the gas in the solution.

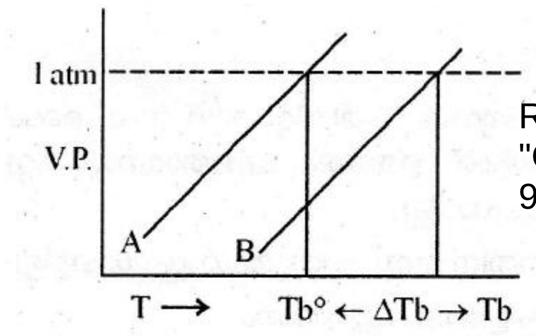
Mathematically, $p = K_H.x$ *(where p is the partial pressure, x is the mole fraction and* K_H *is the Henry's law constant).*

(ii) In the preparation of soda water the bottle is sealed at high pressure, a condition known as Bends in Scuba divers, a medical condition known as Anoxia in people living at high altitudes or climbers. (Any 2 applications)

(b) Given V = 1000 cm³ = 1 L, w_2 = 1.26 g, π = 2.57 x 10^{-3} bar, T = 300 K, R = 0.083 Lbar$K^{-1}mol^{-1}$

$$M_2 = \frac{w_2RT}{\pi V} = \frac{1.26 \times 0.083 \times 300}{2.57 \times 10^{-3} \times 1} = 12.2077 \times 10^3 \text{ g/mol}$$

15. a) The mole fraction of water in a mixture containing equal number of moles of water and ethanol is:
    i) 1 ii) 0.5 iii) 2 iv) 0.25 (1)
    b) The following are the vapour pressure curves of a pure solvent and a solution of a non-volatile solute in it.



Based on the above curves answer the following questions.
i) What do the curves A and B indicates? (1)
ii) Explain why the value of T_b is greater than that of T_b^0. (2) [SAY 2017]

Ans: a) 0.5

b) i) A – Pure solvent and B – Solution

ii) Since the solute is non-volatile, the vapour pressure of solution is always less than that of the pure solvent. So it boils at higher temperature.

16. A solution contains 15 g urea (molar mass = 60 g mol^{-1}) per litre of solution in water has the same osmotic pressure as a solution of glucose (molar mass = 180 g mol^{-1}) in water. Calculate the mass of glucose present in one litre of its solution. (2)

Ans: Here the two solutions have same osmotic pressure. So they are isotonic. Hence $\pi_1 = \pi_2$.

We know that $\pi = nRT/V$

Therefore, $\pi_1 = n_1RT/V$

And $\pi_2 = n_2RT/V$

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Since $\pi_1 = \pi_2$, it follows that $n_1 = n_2$ (at constant temperature and volume)

Or, $w_1/M_1 = w_2/M_2$ (Here 1 indicates urea and 2 indicates glucose)

Or, $15/60 = w_2/180$

So, $w_2 = 15 \times 180/60 = 45g$

i.e. Mass of glucose = 45g

17. Define minimum boiling azeotropes with example. (2) [March 2018]

Ans: The solutions which show a large positive deviation from Raoult's law form minimum boiling azeotrope at a particular composition. E.g. 95% ethanol solution by volume.

18. Draw the vapour pressure-mole fraction curve for a non-ideal solution having positive deviation, if A and B are the two volatile components. (2)

Ans: Refer the Answer of Question no. 11 (c)

19. Calculate the depression in freezing point of a 0.2 molal solution if k_f for water is 1.86 K kg mol^{-1}. (2) [SAY 2018]

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We know that, $\Delta T_f = k_f.m = 1.86 \times 0.2 = 0.372$ K

20. What is reverse osmosis? Write ally one of its applications. (2)

Ans: If a pressure larger than the osmotic pressure is applied to the solution side, the direction of osmosis gets reversed (i.e. now the pure solvent flows out of the solution through the semi permeable membrane). This phenomenon is called reverse osmosis.

It is used in desalination of sea water.

21. A 5% solution (by mass) of cane sugar ($C_{12}H_{22}O_{11}$)) in water has a freezing point of 271K. Calculate the freezing point of 5% (by mass) solution of glucose ($C_6H_{12}O_6$) in water. Freezing point of pure water is 273.15 K. (3)

[March 2019]

Ans: We know that $\Delta T_f = \frac{1000\, K_f .\, w_2}{w_1 .\, M_2}$

5% cane sugar ($C_{12}H_{22}O_{11}$) solution by mass means 5g cane sugar is present in 100g solution.

So, Mass of cane sugar (w_2) = 5g, Mass of solvent, water (w_1) = 100 – 5 = 95g

Molar mass of cane sugar (M_2) = 342 g/mol, freezing point of solution (T_f) = 271 K, freezing point of pure water ($T_f^{\,0}$) = 273.15 K.

So $\Delta T_f = T_f^0 - T_f = 273.15 - 271 = 2.15$ K

$$K_f = \frac{\Delta T_f .\, w_1 . M_2}{1000 \times w_2} = \frac{2.15 \times 95 \times 342}{1000 \times 5} = 13.97 \text{ K/molal}$$

5% glucose solution by mass means 5g glucose is present in 100g solution.

So, Mass of glucose (w_2) = 5g, Mass of slovent (w_1) = 100 – 5 = 95g

Molar mass of glucose (M_2) = 180g/mol, K_f = 13.97 K/molal

Therefore, $\Delta T_f = \frac{1000 \times 13.97 \times 5}{95 \times 180} = 4.085$ K

Also, $\Delta T_f = T_f^0 - T_f$

Therefore, freezing point of solution, $T_f = T_f^0 - \Delta T_f = 273.15 - 4.085 = \underline{269.065 \text{ K}}$

22. Which of the following is not a colligative property?

(a) Osmotic pressure (b) Vapour pressure (c) Elevation of boiling point (d) Depression of freezing point (1)

Ans: (b) Vapour pressure

23. What is meant by positive and negative deviation from Raoult's law and how is the sign of $\Delta_{mix}H$ related to positive and negative deviation ? (3) [SAY 2019]

Ans: These are related to non-ideal solution. Positive deviation from Raoult's law means their actual vapour pressure is greater than that predicted by Raoult's law. This is because here the solute-solvent interactions are weaker than solute-solute and solvent-solvent interactions. For such solutions, $\Delta_{mix}H$ is positive. i.e. on mixing the components, heat is absorbed.

Negative deviation from Raoult's law means their actual vapour pressure is less than that predicted by Raoult's law. Here the solute-solvent interactions are stronger than solute-solute and solvent-solvent interactions. For such solutions, $\Delta_{mix}H$ is negative. i.e. on mixing the components, heat is evolved.

24. For ethanol-acetone mixture solute-solvent interaction is weaker than solute-solute and solvent-solvent interaction.

a) Does this solution obey Raoult's law? (1)

b) Give the vapour pressure-mole fraction graph for this solution. (2) [March 2020]

Ans: a) No. This mixture shows positive deviation from Raoult's law.

b) Refer the answer of question no. 11 (c)

25. Complete the table by giving the value of Van't Hoff factor 'I' for complete dissociation of solute. (2)

Salt	Van't Hoff factor 'i' for complete dissociation of solute
NaCl	
$Al(NO_3)_3$	
K_2SO_4	
$Al_2(SO_4)_3$	

Ans:

Salt	*NaCl*	*$Al(NO_3)_3$*	*K_2SO_4*	*$Al_2(SO_4)_3$*
Van't Hoff factor 'i'	*2*	*4*	*3*	*5*

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