# Solutions

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**1. For an electrolyte undergoing association in a solvent, the van't Hoff factor: (2024)**

(A) is always greater than one

(B) has negative value

(C) has zero value

(D) is always less than one

**Ans.** (D) is always less than one

**2. two statements are given - one labelled as Assertion (A) and the other labelled as Reason (R). Select the correct answer to these questions from the codes (A), (B), (C) and (D) as given below. (2024)**

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

**Assertion (A) :** When NaCl is added to water a depression in freezing point is observed.

**Reason (R) :** NaCl undergoes dissociation in water.

**Ans.** (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

**3. (i) At the same temperature, $CO_2$ gas is more soluble in water than $O_2$ gas. Which one of them will have higher value of $K_H$ and why ? (2024)**

**(ii) How does the size of blood cells change when placed in an aqueous solution containing more than 0·9% (mass/volume) sodium chloride ?**

**(iii) 1 molal aqueous solution of an electrolyte $A_2B_3$ is 60% ionized. Calculate the boiling point of the solution. (Given : $K_b$ for $H_2O = 0{\cdot}52$ K kg mol$^{-1}$)**

**Ans.**

(i) As $K_H \propto \frac{1}{\text{Solubility}}$ of Gas

$\therefore O_2$ gas has higher $K_H$; because higher the $K_H$ value, lower the solubility of gas in liquid.

(ii) Blood cells shrink.

(iii) $\Delta T_b = iK_b m$

$T_b - T_b^0 = i \times 0{\cdot}52 \text{ K Kg mol}^{-1} \times 1 \text{ mol Kg}^{-1}$

$\alpha = \frac{i-1}{n-1}$

n=5

$0{\cdot}6 = \frac{i-1}{5-1}$

$i = 3{\cdot}4$

$T_b - 373 \text{ K} = 3{\cdot}4 \times 0{\cdot}52 \times 1$

$T_b = 1{\cdot}768 + 373 \text{ K}$

$T_b$=374.768K(If boiling point of water is 373.15K then $T_b$= 374.918K)

**4. (i) The vapour pressures of A and B at 25ºC are 75 mm Hg and 25 mm Hg, respectively. If A and B are mixed such that the mole fraction of A in the mixture is 0·4, then calculate the mole fraction of B in vapour phase. (2024)**

**Ans.**

(i) $P_T = p_A{}^0 x_A + p_B{}^0 x_B$

$P_T = 75 \times 0{\cdot}4 + 25 \times 0{\cdot}6$

$P_T = 30 + 15 = 45$ mm Hg

In Vapour phase

$p_B = y_B \times P_T$

$y_B = p_B / P_T = \frac{p_B^o x_B}{P_T}$

$y_B = \frac{15}{45} = \frac{1}{3} = 0{\cdot}33$ mm Hg

**(ii) Define colligative property. Which colligative property is preferred for the molar mass determination of macromolecules ?**

**Ans.** The property which depends upon the number of solute particles but not on the nature of solute.; Osmotic pressure.

**5. Why are equimolar solutions of sodium chloride and glucose not isotonic ?**

**(2024)**

**Ans.** Because sodium chloride undergoes dissociation (i=2) in water while glucose does not. / л= ¡CRT; For NaCl, i=2 and for glucose i=1.

# Previous Years' CBSE Board Questions

## 1.2 Expressing Concentration of Solutions

### Mass Percentage, Mole Fraction, Molarity, Molality

**MCQ**

1. **Assertion (A) :** Molality of a solution in liquid state changes with temperature.
   **Reason (R) :** The volume of solution changes with the change in temperature.
   (a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of Assertion (A).
   (b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of Assertion (A).
   (c) Assertion (A) is correct, but Reason (R) is incorrect statement.
   (d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(2020 C)*
2. 50 mL of an aqueous solution of glucose $C_6H_{12}O_6$ (Molar mass : 180 g/mol) contains $6.02 \times 10^{22}$ molecules. The concentration of the solution will be
   (a) 0.1 M (b) 0.2 M
   (c) 1.0 M (d) 2.0 M *(2020)*

**VSA (1 mark)**

3. Define the following term : Molality ($m$)
   *(NCERT, 1/2, Delhi 2017, 1/5 AI 2014 C)* R
4. Define the following term : Molarity ($M$)
   *(NCERT, 1/2, Delhi 2017, 1/5 AI 2014)* R
5. Define the following term :
   Mole fraction *(NCERT, 1/5 AI 2014 C)* R

**SA I (2 marks)**

6. Calculate the molarity of 9.8% (*w*/*W*) solution of $H_2SO_4$ if the density of the solution is 1.02 g $mL^{-1}$. (Molar mass of $H_2SO_4$ = 98 g $mol^{-1}$)
   *(2/5, Foreign 2014)* Ev
7. Differentiate between molarity and molality of a solution. How can we change molality value of a solution into molarity value? *(Delhi 2014 C)* An

**SA II (3 marks)**

8. A solution of glucose (molar mass = 180 g $mol^{-1}$) in water is labelled as 10% (by mass). What would be the molality and molarity of the solution?
   (Density of solution = 1.2 g $mL^{-1}$)
   *(NCERT, 3/5, AI 2014)*

## 1.3 Solubility

### Solubility of Gas in a Liquid (Henry's Law)

**MCQ**

9. On dissolving ammonium chloride in water at room temperature, the solution feels cool to touch. Under which of the following conditions does salt dissolve faster?
   (a) Powdered salt in cold water
   (b) Powdered salt in hot water
   (c) Salt crystals in cold water
   (d) Salt crystals in hot water *(2023)*
10. Low concentration of oxygen in the blood and tissues of people living at high altitude is due to
    (a) high atmospheric pressure
    (b) low temperature
    (c) low atmospheric pressure
    (d) both low temperature and high atmospheric pressure. *(2023)*
11. 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
    *(Term I, 2021-22)* An

**VSA (1 mark)**

12. Why aquatic animals are more comfortable in cold water than in warm water? *(1/3, 2018)* Ap
13. Gas (*A*) is more soluble in water than gas (*B*) at the same temperature. Which one of the two gases will have the higher value of $K_H$ (Henry's constant) and why?
    *(1/2, AI 2016)*

**SA I (2 marks)**

14. What is Henry's law? Give one application of it. *(2023)*
15. State Henry's law. Why is air diluted with helium in the tanks used by scuba divers? *(2/5, 2020)* An
16. State Henry's law. Calculate the solubility of $CO_2$ in water at 298 K under 760 mm Hg.
    ($K_H$ for $CO_2$ in water at 298 K is $1.25 \times 10^6$ mm Hg) *(2020)*
17. State Henry's law and mention two of its important applications. *(2020 C)* U
18. Give reasons for the following.
    (a) Aquatic species are more comfortable in cold water than in warm water.
    (b) At higher altitudes people suffer from anoxia resulting in inability to think. *(AI 2019)* Ap

## 1.4 Vapour Pressure of Liquid Solutions

### Raoult's Law

#### MCQ

19. Which of the following formula represents Raoult's law for a solution containing non-volatile solute?
    (a) $p_{solute} = p^{\circ}_{solute} \cdot x_{solute}$
    (b) $p = K_H \cdot x$
    (c) $P_{total} = p_{solvent}$
    (d) $p_{solute} = p^{\circ}_{solvent} \cdot x_{solvent}$
    *(Term I, 2021-22)* U

#### VSA (1 mark)

20. Identify which liquid will have a higher vapour pressure at 90°C if the boiling points of two liquids *A* and *B* are 140°C and 180°C, respectively. *(One word, 2020)* U

21. Define Raoult's law. *(1/5 AI 2014C)*

#### SA I (2 marks)

22. State Raoult's law for a solution containing volatile components. What is the similarity between Raoult's law and Henry's law? *(2020, Delhi 2014)* R

23. State Raoult's law for a solution containing volatile components. Name the solution which follows Raoult's law at all concentrations and temperatures. *(2/5, Foreign 2014)* R

## 1.5 Ideal and Non-ideal Solutions

### Ideal Solutions

#### MCQ

24. 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 *(Term I, 2021-22)* Ap

#### VSA (1 mark)

25. Define the following term : Ideal solution *(1/2, Delhi 2017, 1/5, AI 2017 C)*

#### SA II (3 marks)

26. (a) Differentiate between Ideal solution and Non-ideal solution.
    (b) 30 g of urea is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg. *(2023)*

### Non-ideal Solutions

#### MCQ

27. On mixing 20 mL of acetone with 30 mL of chloroform, the total volume of the solution is
    (a) < 50 mL (b) = 50 mL
    (c) > 50 mL (d) = 10 mL
    *(Term I, 2021-22)* Ev

#### VSA (1 mark)

28. What happens when acetone is added to pure ethanol? *(1/2, 2020)* Ev

#### SA I (2 marks)

29. What type of deviation from Raoult's law is observed by mixing chloroform and acetone?
    Why is a decrease in a vapour pressure observed in mixing chloroform and acetone? *(2021C)* Ap

30. Write two differences between ideal solutions and non-ideal solutions. *(2/3, 2020 C, Delhi 2019, 2/5, AI 2017)*

31. What is meant by positive deviations from Raoult's law? Give an example. What is the sign of $\Delta_{mix}H$ for positive deviation? *(Delhi 2015)*

    **OR**

    What is meant by negative deviation from Raoult's law? Give an example. What is the sign of $\Delta_{mix}H$ for negative deviation? *(Foreign 2015)*

32. What type of deviation is shown by a mixture of ethanol and acetone? Give reason. *(2/5, AI 2014)*

### Azeotropes

#### MCQ

33. 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. *(Term I, 2021-22)*

#### VSA (1 mark)

34. In non-ideal solution, what type of deviation shows the formation of maximum boiling azeotropes? *(1/2, AI 2016)*

35. Some liquids on mixing form 'azeotropes'. What are 'azeotropes'? *(Delhi 2014)*

    **OR**

    Define the following term :
    Azeotrope *(1/5, Foreign 2014)*

#### SA I (2 marks)

36. What type of azeotropic mixture will be formed by a solution of acetone and chloroform? Justify on the basis of strength of intermolecular interactions that develop in the solution. *(AI 2019)* U

37. Define azeotropes. What type of azeotrope is formed by positive deviation from Raoult's law? Give an example. *(Delhi 2015)*

38. Define azeotropes. What type of azeotrope is formed by negative deviation from Raoult's law? Give an example. *(Foreign 2015)*

## 1.6 Colligative Properties and Determination of Molar Mass

### Relative Lowering in Vapour Pressure

**VSA** **(1 mark)**

39. Define the following term :
Colligative properties *(1/2, Delhi 2017)*

40. How is the vapour pressure of a solvent affected when a non-volatile solute is dissolved in it?
*(1/2, Delhi 2014C)* U

**SA I** **(2 marks)**

41. A solution is prepared by dissolving 10 g of non-volatile solute in 200 g of water. It has a vapour pressure of 31.84 mm Hg at 308 K. Calculate the molar mass of the solute.
(Vapour pressure of pure water at 308 K = 32 mm Hg) *(2023)*

**SA II** **(3 marks)**

42. Give reasons :
(a) Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers.
(b) Aquatic animals are more comfortable in cold water than in warm water.
(c) Elevation of boiling point of 1 M KCl solution is nearly double than that of 1 M sugar solution. *(2023)*

43. Vapour pressure of water at 293 K is 17·536 mm Hg. Calculate the vapour pressure of aqueous solution when 20 g of glucose (Molar mass = 180 g $\text{mol}^{-1}$) is dissolved in 500 g of water. *(2021 C)*

44. 30 g of urea ($M$ = 60 g $\text{mol}^{-1}$) is dissolved in 846 g of water. Calculate the vapour pressure of water for this solution if vapour pressure of pure water at 298 K is 23.8 mm Hg. *(3/5, AI 2017)*

**LA** **(5 marks)**

45. (a) State Henry's law and mention its two applications.
(b) 5% aqueous solution of a non-volatile solute was made and its vapour pressure at 373 K was found to be 745 mm. Vapour pressure of pure water at this temperature was 760 mm. Calculate the molar mass of solute.
*(2020C)* Ap

### Elevation of Boiling Point

**MCQ**

46. The boiling point of a 0.2 m solution of a non-electrolyte in water is
($K_b$ for water = 0.52 K kg $\text{mol}^{-1}$)
(a) 100 °C (b) 100.52 °C
(c) 100.104 °C (d) 100.26 °C
*(Term I, 2021-22)* Cr

47. **Assertion (A) :** Elevation in boiling point is a colligative property.
**Reason (R) :** Elevation in boiling point is directly proportional to molarity.
(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is correct, but Reason (R) is wrong statement.
(d) Assertion (A) is wrong, but Reason (R) is correct statement. *(2020)* R

**VSA** **(1 mark)**

48. Define the following term :
Molal elevation constant ($K_b$) *(1/5, AI 2014)*

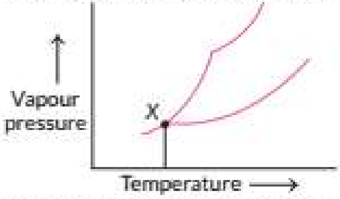
**SA I** **(2 marks)**

49. Why does a solution containing non-volatile solute have higher boiling point than the pure solvent? Why is elevation of boiling point a colligative property?
*(AI 2015)* An

### Depression of Freezing Point

**MCQ**

50. 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.
*(Term I, 2021-22)* Cr

**SA I** **(2 marks)**

51. Nisha took two aqueous solutions – one containing 7.5 g of urea (Molar mass = 60 g/mol) and the other containing 42.75 g of substance $Z$ in 100 g of water, respectively. It was observed that both the solutions froze at the same temperature. Calculate the molar mass of $Z$. *(2020)* Ev

52. Calculate the freezing point of a solution containing 60 g of glucose (molar mass = 180 g mol$^{-1}$) in 250 g of water. ($K_f$ of water = 1.86 K kg mol$^{-1}$) *(2018)*

53. Calculate the mass of compound (molar mass = 256 g mol$^{-1}$) to be dissolved in 75 g of benzene to lower its freezing point by 0.48 K. ($K_f$ = 5.12 K kg mol$^{-1}$). *(Delhi 2014)*

### SA II (3 marks)

54. An antifreeze solution is prepared by dissolving 31 g of ethylene glycol (Molar mass = 62 g mol$^{-1}$) in 600 g of water. Calculate the freezing point of the solution. ($K_f$ for water = 1.86 K kg mol$^{-1}$) *(2020)*

55. Calculate the mass of ascorbic acid (Molar mass = 176 g mol$^{-1}$) to be dissolved in 75 g of acetic acid, to lower its freezing point by 1.5°C. ($K_f$ = 3.9 K kg mol$^{-1}$) *(NCERT Intext, 2020)*

56. A 4% solution (*w*/*w*) of sucrose (*M* = 342 g mol$^{-1}$) in water has a freezing point of 271.15 K. Calculate the freezing point of 5% glucose (*M* = 180 g mol$^{-1}$) in water. (Given : Freezing point of pure water = 273.15 K) *(Delhi 2019)* Ev

57. 1.00 g of a non-electrolyte solute dissolved in 50 g of benzene lowered the freezing point of benzene by 0.40 K. The freezing point depression constant of benzene is 5.12 K kg mol$^{-1}$. Find the molar mass of the solute. *(3/5, Delhi 2019 C)*

58. A 5% solution (by mass) of cane-sugar in water has freezing point of 271 K. Calculate the freezing point of 5% solution (by mass) of glucose in water if the freezing point of pure water is 273.15 K.
[Molecular masses : Glucose $C_6H_{12}O_6$ : 180 amu; Cane-sugar $C_{12}H_{22}O_{11}$ : 342 amu]
*(NCERT, 3/5, Delhi 2019C)* Ev

59. A 10% solution (by mass) of sucrose in water has freezing point of 269.15 K. Calculate the freezing point of 10% glucose in water, if freezing point of pure water is 273.15 K.
(Given : Molar mass of sucrose = 342 g mol$^{-1}$,
molar mass of glucose = 180 g mol$^{-1}$) *(Delhi 2017)* Ev

60. Calculate the freezing point of the solution when 31 g of ethylene glycol ($C_2H_6O_2$) is dissolved in 500 g of water. ($K_f$ for water = 1.86 K kg mol$^{-1}$) *(AI 2015)*

61. Some ethylene glycol, $HOCH_2CH_2OH$, is added to your car's cooling system along with 5 kg of water. If the freezing point of water-glycol solution is −15.0°C, what is the boiling point of the solution?
($K_b$ = 0.52 K kg mol$^{-1}$ and $K_f$ = 1.86 K kg mol$^{-1}$ for water) *(Delhi 2014 C)*

## Osmosis and Osmotic Pressure

### MCQ

62. The colligative property used for the determination of molar mass of polymers and proteins is
    (a) osmotic pressure
    (b) depression in freezing point
    (c) relative lowering in vapour pressure
    (d) elevation in boiling point. *(2023)*

63. **Assertion(A) :** A raw mango placed in saline solution loses water and shrivel into pickle.
**Reason (R) :** Through the process of reverse osmosis raw mango shrivel into pickle.
    (a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
    (b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
    (c) Assertion (A) is correct, but Reason (R) is incorrect statement.
    (d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(Term I, 2021-22)* Ap

64. **Assertion (A) :** Osmotic pressure is a colligative property.
**Reason (R) :** Osmotic pressure is directly proportional to molarity.
    (a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
    (b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
    (c) Assertion (A) is correct, but Reason (R) is incorrect statement.
    (d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(2020)*

### VSA (1 mark)

65. What happens when a pressure greater than osmotic pressure is applied on the solution side separated from solvent by a semi-permeable membrane? *(1/2, 2020)* Ap

66. Give reason for the following :
Measurement of osmotic pressure method is preferred for the determination of molar masses of macromolecules such as proteins and polymers. *(1/2, 2018)* U

67. Define the following term :
Osmotic pressure *(1/5, AI 2017 C)* R

68. What are isotonic solutions? *(Delhi 2014)* R

### SA I (2 marks)

69. For a 5% solution of urea (Molar mass = 60 g/mol), calculate the osmotic pressure at 300 K. [$R$ = 0.0821 L atm K$^{-1}$ mol$^{-1}$] *(2020)*

70. Give reasons :
    (a) Cooking is faster in pressure cooker than in cooking pan.
    (b) Red Blood Cells (RBC) shrink when placed in saline water but swell in distilled water. *(2019)*

71. (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? *(2/5, Delhi 2016)* An

72. 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?
    *(2/5, Delhi 2016)* Ap

**SA II (3 marks)**

73. At 300 K, 30 g of glucose present in a litre of its solution has an osmotic pressure of 4.98 bar. If the osmotic pressure of a glucose solution is 1.52 bar at the same temperature, what would be its concentration? *(AI 2019)*

74. A solution containing 15 g urea (molar mass = 60 g mol$^{-1}$) per litre of solution in water has the same osmotic pressure (isotonic) 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. *(3/5, AI 2014)*

75. Define the following terms :
    (i) Osmotic pressure
    (ii) Colligative properties *(Foreign 2014)* R

## 1.7 Abnormal Molar Masses

### van't Hoff and Abnormal Molar Mass

**VSA (1 mark)**

76. Define the following term :
    van't Hoff factor *(Delhi 2017)*

77. Define the following term :
    Abnormal molar mass *(Delhi 2017)*

**SA I (2 marks)**

78. Predict the state of the solute in the solution in the following situations :
    (a) When '*i*' is found to be more than one.
    (b) When '*i*' is found to be less than one. *(2020)*

79. What is van't Hoff factor? What types of values can it have if in forming the solution the solute molecules undergo
    (i) dissociation
    (ii) association? *(2/5, AI 2014 C)* U

### van't Hoff and Elevation in Boiling Point

**VSA (1 mark)**

80. Give reason for the following :
    Elevation of boiling point of 1 M KCl solution is nearly double than that of 1 M sugar solution.
    *(1/2, 2018)* U

**SA I (2 marks)**

81. Give reasons :
    (i) 0.1 M KCl has higher boiling point than 0.1 M glucose.
    (ii) Meat is preserved for a longer time by salting.
    *(2020)* An

**SA II (3 mark)**

82. (a) Out of 0·1 molal aqueous solution of glucose and 0·1 molal aqueous solution of KCl, which one will have higher boiling point and why ?
    (b) Predict whether van't Hoff factor, (*i*) is less than one or greater than one in the following :
    (i) $CH_3COOH$ dissolved in water
    (ii) $CH_3COOH$ dissolved in benzene *(2019)*

83. 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 = 0.52 K kg mol$^{-1}$, molar mass of $CaCl_2$ = 111 g mol$^{-1}$) *(3/5, AI 2017C, Foreign 2014)*

84. Calculate the boiling point of solution when 4 g of $MgSO_4$ ($M$ = 120 g mol$^{-1}$) was dissolved in 100 g of water, assuming $MgSO_4$ undergoes complete ionization.
    ($K_b$ for water = 0.52 K kg mol$^{-1}$) *(AI 2016)*

**LA (5 marks)**

85. (i) Why is boiling point of 1 M NaCl solution more than that of 1 M glucose solution?
    (ii) A non-volatile solute *X* (molar mass = 50 g mol$^{-1}$) when dissolved in 78 g of benzene reduced its vapour pressure to 90%. Calculate the mass of *X* dissolved in the solution.
    (iii) Calculate the boiling point of elevation for a solution prepared by adding 10g of $MgCl_2$ to 200 g of water assuming $MgCl_2$ is completely dissociated.
    ($K_b$ for water = 0.512 K kg mol$^{-1}$, molar mass $MgCl_2$ = 95 g mol$^{-1}$) *(2023)*

### van't Hoff and Depression in Freezing Point

**MCQ**

86. Out of the following 1.0 M aqueous solutions which one will show largest freezing point depression?
    (a) NaCl (b) $Na_2SO_4$
    (c) $C_6H_{12}O_6$ (d) $Al_2(SO_4)_3$ *(2023)*

**SA I (2 marks)**

87. Assuming complete dissociation, calculate the expected freezing point of a solution prepared by dissolving 6.00 g of Glauber's salt, $Na_2SO_4{\cdot}10H_2O$ in 0.100 kg of water. ($K_f$ for water = 1.86 K kg mol$^{-1}$, atomic masses : Na = 23, S = 32, O = 16, H = 1)
    *(2/5, AI 2014C)* Ap

**SA II (3 marks)**

88. When 19.5 g of F—$CH_2$—COOH (molar mass = 78 g mol$^{-1}$) is dissolved in 500 g of water, the depression

in freezing point is observed to be 1°C. Calculate the degree of dissociation of F—$CH_2$—COOH.
[Given : $K_f$ for water = 1.86 K kg $mol^{-1}$] *(3/5, 2020)* Ev

89. The freezing point of a solution containing 5 g of benzoic acid ($M$ = 122 g $mol^{-1}$) in 35 g of benzene is depressed by 2.94 K. What is the percentage association of benzoic acid if it forms a dimer in solution? ($K_f$ for benzene = 4.9 K kg $mol^{-1}$) *(2020)* An

90. A 0.01 m aqueous solution of $AlCl_3$ freezes at −0.068 °C. Calculate the percentage of dissociation.
[Given : $K_f$ for water = 1.86 K kg $mol^{-1}$] *(2020)* Ev

91. Calculate the freezing point of solution when 1.9 g of $MgCl_2$ ($M$ = 95 g $mol^{-1}$) was dissolved in 50 g of water, assuming $MgCl_2$ undergoes complete ionization.
($K_f$ for water = 1.86 K kg $mol^{-1}$) *(Delhi 2016)*

92. 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 $mol^{-1}$, atomic mass of sulphur = 32 g $mol^{-1}$)
*(3/5 Delhi 2016)* Cr

93. 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 $mol^{-1}$) *(Delhi 2015)* Ev

94. Calculate the mass of NaCl (molar mass = 58.5 g $mol^{-1}$) to be dissolved in 37.2 g of water to lower the freezing point by 2°C, assuming that NaCl undergoes complete dissociation. ($K_f$ for water = 1.86 K kg $mol^{-1}$)
*(Foreign 2015)*

**LA** **(5 marks)**

95. (a) Give two differences between ideal and non-ideal solutions.
    (b) Calculate the amount of NaCl ($M$ = 58.5 g $mol^{-1}$) that must be added to 100 g of water so that freezing point is depressed by 2 K. $K_f$ for water is 1.86 K/m. *(2020C)*

96. (a) Write two characteristics of non-ideal solution.
    (b) 2 g of benzoic ($C_6H_5COOH$) dissolved in 25 g of benzene shows a depression in freezing point equal to 1.62 K. Molal depression constant for benzene is 4.9 K kg $mol^{-1}$. What is the percentage association of acid if it forms dimer in solution ? *(2019)*

## van't Hoff and Osmotic Pressure

**SA II** **(3 marks)**

97. A solution contains 5.85 g NaCl (Molar mass = 58.5 g $mol^{-1}$) per litre of solution. It has an osmotic pressure of 4.75 atm at 27°C. Calculate the degree of dissociation of NaCl in this solution.
(Given : $R$ = 0.082 L atm $K^{-1}$ $mol^{-1}$) *(3/5, 2020)*

98. A solution 0.1 M of $Na_2SO_4$ is dissolved to the extent of 95%. What would be its osmotic pressure at 27°C? ($R$ = 0.0821 L atm $K^{-1}$ $mol^{-1}$) *(2019)*

99. (a) Draw the graph between vapour pressure and temperature and explain the elevation in boiling point of a solvent in solution.
    (b) Determine the osmotic pressure of a solution prepared by dissolving 25 mg of $K_2SO_4$ in 2 litres of water at 25°C assuming it to be completely dissociated.
    (Atomic masses : K = 39 u, S = 32 u, O = 16 u) *(2019)*

**LA** **(5 marks)**

100. (i) What is the value of van't Hoff factor for ethanoic acid in benzene close to 0.5?
    (ii) Determine the osmotic pressure of a solution prepared by dissolving 2.32 × $10^{-2}$ g of $K_2SO_4$ in 2 L of solution at 25°C, assuming that $K_2SO_4$ is completely dissociated.
    (iii) When 25.6 g of sulphur was dissolved in 1000 g of benzene, the freezing point lowered by 0.512 K. Calculate the formula of sulphur ($S_x$).
    ($K_f$ for benzene = 5.12 K kg $mol^{-1}$, Atomic mass of sulphur = 32 g $mol^{-1}$) *(2023)*

# CBSE Sample Questions

## 1.2 Expressing Concentration of Solutions

**MCQ**

1. Given below are two statements labelled as assertion (A) and Reason (R).
**Assertion (A) :** Molarity of a solution changes with temperature.
**Reason (R) :** Molarity is a colligative property.
Select the most appropriate answer from the options given below:
(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true. *(Term I, 2021-22)* R

## 1.3 Solubility

**MCQ**

2. Solubility of gases in liquids decreases with rise in temperature because dissolution is an

(a) endothermic and reversible process
(b) exothermic and reversible process
(c) endothermic and irreversible process
(d) exothermic and irreversible process.

*(Term I, 2021-22)*

**In the following question a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following.**

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

3. **Assertion :** Aquatic species are more comfortable in cold waters rather than in warm waters.
**Reason :** Different gases have different $K_H$ values at the same temperature. *(2020-21)*

**SA II (3 marks)**

4. Answer the following questions :
   (a) State Henry's law and explain why are the tanks used by scuba divers filled with air diluted with helium (11.7% helium, 56.2% nitrogen and 32.1% oxygen)?
   (b) Assume that argon exerts a partial pressure of 6 bar. Calculate the solubility of argon gas in water. (Given Henry's law constant for argon dissolved in water, $K_H$ = 40 kbar) *(2022-23)*

## 1.4 Vapour Pressure of Liquid Solutions

**MCQ**

5. Identify the law which is stated as
"For any solution, the partial vapour pressure of each volatile component in the solution is directly proportional to its mole fraction."
(a) Henry's law (b) Raoult's law
(c) Dalton's law (d) Gay-Lussac's Law
*(Term I, 2021-22)* Ap

6. When 1 mole of benzene is mixed with 1 mole of toluene the vapour will contain
(Given : Vapour pressure of benzene = 12.8 kPa and vapour pressure of toluene = 3.85 kPa).
(a) equal amount of benzene and toluene as it forms an ideal solution
(b) unequal amount of benzene and toluene as it forms a non-ideal solution
(c) higher percentage of benzene
(d) higher percentage of toluene. *(2020-21)* U

## 1.5 Ideal and Non-ideal Solutions

**MCQ**

**In the following question a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following.**

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is not the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

7. **Assertion :** Nitric acid and water form maximum boiling azeotrope.
**Reason :** Azeotropes are binary mixtures having the same composition in liquid and vapour phase.
*(2020-21)*

## 1.6 Colligative Properties and Determination of Molar Mass

**MCQ**

8. In which of the following cases blood cells will shrink?
   (a) When placed in water containing more than 0.9% (mass/ volume) NaCl solution.
   (b) When placed in water containing less than 0.9% (mass /volume) NaCl solution.
   (c) When placed in water containing 0.9% (mass/ volume) NaCl solution.
   (d) When placed in distilled water.
*(Term I, 2021-22)* An

9. How much ethyl alcohol must be added to 1 litre of water so that the solution will freeze at – 14°C ? ($K_f$ for water = 1.86°C/mol)
(a) 7.5 mol (b) 8.5 mol
(c) 9.5 mol (d) 10.5 mol
*(Term I, 2021-22)*

10. Water retention or puffiness due to high salt intake occurs due to
    (a) diffusion
    (b) vapour pressure difference
    (c) osmosis
    (d) reverse osmosis. *(Term I, 2021-22)*

11. Given below are two statements labelled as assertion (A) and Reason (R).
**Assertion (A) :** Cryoscopic constant depends on nature of solvent.
**Reason (R) :** Cryoscopic constant is a universal constant.
Select the most appropriate answer from the options given below:
    (a) Both A and R are true and R is the correct explanation of A.
    (b) Both A and R are true but R is not the correct explanation of A.

(c) A is true but R is false.

(d) A is false but R is true. *(2020-21)* U

**SA I** (2 marks)

12. A glucose solution boils at 101.04°C at 1 atm. What will be relative lowering of vapour pressure of an aqueous solution of urea which is equimolal to given glucose solution?
(Given : $K_b$ for water is 0.52 K kg mol$^{-1}$) *(2020-21)* Ev

## 1.7 Abnormal Molar Masses

**Case Based** (4 marks)

13. Henna is investigating the melting point of different salt solutions.
She makes a salt solution using 10 mL of water with a known mass of NaCl salt.
She puts the salt solution into a freezer and leaves it to freeze. She takes the frozen salt solution out of the freezer and measures the temperature when the frozen salt solution melts. She repeats each experiment.

| S.No. | Mass of the salt used in g | Melting point in °C | |
|---|---|---|---|
| | | Readings Set 1 | Readings Set 2 |
| 1 | 0.3 | −1.9 | −1.9 |
| 2 | 0.4 | −2.5 | −2.6 |
| 3 | 0.5 | −3.0 | −5.5 |
| 4 | 0.6 | −3.8 | −3.8 |
| 5 | 0.8 | −5.1 | −5.0 |
| 6 | 1.0 | −6.4 | −6.3 |

**Assuming the melting point of pure water as 0°C, answer the following questions :**

(a) One temperature in the second set of results does not fit the pattern. Which temperature is that? Justify your answer.

(b) Why did Henna collect two sets of results?

(c) In place of NaCl, if Henna had used glucose, what would have been the melting point of the solution with 0.6 g glucose in it?

OR

What is predicted melting point, if 1.2 g of salt is added to 10 mL of water? Justify your answer.

*(2022-23)*

# Detailed SOLUTIONS

## *Previous Years' CBSE Board Questions*

1. (d): Molality of a solution in liquid state does not change with temperature as mass does not change with temperature. The volume of solution changes with change in temperature so, does the molarity changes.

2. (d): 1 mole of glucose = $N_A$ molecules

$$6.02 \times 10^{22} \text{ molecules} = \frac{1}{N_A} \times 6.02 \times 10^{22} \text{ mole} = 0.1 \text{ mole}$$

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (mL)}} \times 1000$$

$$= \frac{0.1}{50} \times 1000 = 2 \text{ mol L}^{-1} \text{ or } 2\text{ M}$$

3. Molality ($m$) is defined as the number of moles of the solute per kilogram of the solvent and is expressed as :

$$\text{Molality } (m) = \frac{\text{Moles of solute}}{\text{Mass of solvent (in kg)}}$$

4. It is the number of moles of the solute dissolved per litre of the solution. It is denoted by $M$.

$$\therefore \quad \text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution in litre}}$$

$$= \frac{n_2}{V(\text{in mL})} \times 1000 = \frac{w_2 \times 1000}{M_2 \times V(\text{in mL})} \qquad \left(\because n_2 = \frac{w_2}{M_2}\right)$$

5. Mole fraction is the ratio of number of moles of solute or solvent to total number of moles of solution. It is denoted by $x$.

$$x_{\text{solute}} = \frac{n_2}{n_1 + n_2}, \; x_{\text{solvent}} = \frac{n_1}{n_1 + n_2}$$

6. Mass of solute = 9.8 g; Mass of solution = 100 g
Density of solution = 1.02 g mL$^{-1}$

$$\therefore \quad \text{Volume of solution} = \frac{\text{Mass of solution}}{\text{Density of solution}}$$

$$= \frac{100 \text{ g}}{1.02 \text{ g mL}^{-1}} = 98.039 \text{ mL} = 0.098 \text{ L}$$

$$\text{Number of moles of solute, } n = \frac{9.8}{98} = 0.1 \text{ mol}$$

$$\text{Molarity} = \frac{\text{Number of moles of solute}}{\text{Volume of solution (in L)}} = \frac{0.1 \text{ mol}}{0.098 \text{ L}} = 1.02 \text{ M}$$

**Answer Tips**

- Remember unit conversion (mL into L), 1 L = 1000 mL

7.

| Molarity | Molality |
|---|---|
| Number of moles of solute dissolved in one litre solution is called molarity. | Number of moles of solute dissolved in one kg solvent is called molality. |
| $M = \dfrac{\text{No. of moles of solute}}{\text{Volume of solution in litre}}$ | $m = \dfrac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$ |
| Molarity depends on temperature as volume depends on temperature. Molarity decreases with rise in temperature. | Molality is independent of temperature as mass does not change with temperature. |

If $M_B$ is the molar mass of solute, $d$ is the density of solution then molality ($m$) of a solution can be converted to molarity ($M$) by using the formula, $M = \dfrac{md}{\left(1+\dfrac{mM_B}{1000}\right)}$

**Commonly Made Mistake**

- Molarity (mol $L^{-1}$), Molality (mol $kg^{-1}$)

8. Given : Mass of solute, $W_2 = 10$ g
Mass of solvent, $W_1 = 90$ g
Molar mass of solute, $M_2 = 180$ g $mol^{-1}$
Density of solution = 1.2 g $mL^{-1}$

$$\text{Molality} = \frac{W_2 \times 1000}{M_2 \times W_1} = \frac{10 \times 1000}{180 \times 90} = 0.62 \text{ m}$$

$$\text{Volume of solution} = \frac{\text{Mass}}{\text{Density}} = \frac{100 \text{ g}}{1.2 \text{ g mL}^{-1}}$$

$$\text{Molarity} = \frac{W_2 \times 1000}{M_2 \times V}$$

$$M = \frac{10 \times 1000}{180 \times \frac{100}{1.2}} = \frac{10 \times 1000 \times 1.2}{180 \times 100} = 0.67 \text{ M}$$

9. (b): Powdered salt dissolves faster in hot water. Dissolution of ammonium chloride in water is an endothermic reaction, hence high temperature will favor the dissolution of ammonium chloride in water.

10. (c): At high altitudes, the partial pressure of oxygen is less than at the ground level. As a result, there is a low concentration of oxygen in the blood and tissues of the people living at high altitudes.

11. (a): According to Henry's law, $p = K_H x$
$2.5 \text{ bar} = K_H \times 0.04$

$$K_H = \frac{2.5}{0.04} = 62.5 \text{ bar}$$

When pressure is doubled, then $x$ is
$5 \text{ bar} = 62.5 \times x \Rightarrow x = 0.08$

12. Increase in temperature decreases the solubility of oxygen in water. As a result, amount of dissolved oxygen decreases. It becomes more difficult to breathe as oxygen is less. Hence, the aquatic species are not comfortable in warm water.

13. According to Henry's law, the solubility of a gas is inversely proportional to the Henry's law constant ($K_H$) for that gas. Hence, gas ($B$) being less soluble, would have a higher $K_H$ value.

14. Henry's law states that the solubility of a gas in a liquid at constant temperature is directly proportional to the pressure of the gas present above the surface of liquid or solution.

$p \propto x$ or $p = K_H x$

Here, $p$ = partial pressure of the gas in vapour phase
$x$ = mole fraction of the gas in the solution
$K_H$ = Henry's law constant

Application of Henry's law :
Soft drinks and soda water bottle are sealed under high pressure to increase the solubility of $CO_2$.

15. Henry's law states that, the partial pressure of the gas in vapour phase ($p$) is proportional to the mole fraction of the gas ($x$) in the solution.
$p = K_H \cdot x$ where, $K_H$ = Henry's law constant. Different gases have different $K_H$ values at the same temperature.
To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.

16. Henry's law states that, the partial pressure of the gas in vapour phase ($p$) is proportional to the mole fraction of the gas ($x$) in the solution.
$p = K_H \cdot x$ where, $K_H$ = Henry's law constant. Different gases have different $K_H$ values at the same temperature.

$$\text{Solubility of } CO_2 = \frac{p}{K_H} = \frac{760}{1.25 \times 10^6} = 6.08 \times 10^{-4}$$

17. Henry's law states that, the partial pressure of the gas in vapour phase ($p$) is proportional to the mole fraction of the gas ($x$) in the solution.
$p = K_H \cdot x$ where, $K_H$ = Henry's law constant. Different gases have different $K_H$ values at the same temperature.
Applications of Henry's law :
(i) To increase the solubility of $CO_2$ in soft drinks and soda water, the bottle is sealed under high pressure.
(ii) To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.

18. (a) Increase in temperature decreases the solubility of oxygen in water. As a result, amount of dissolved oxygen decreases. It becomes more difficult to breathe as oxygen is less. Hence, the aquatic species are not comfortable in warm water.
(b) At high altitudes, the partial pressure of oxygen is less than at the ground level. As a result, there is a low concentration of oxygen in the blood and tissues of the people living at high altitudes. Thus, they feel weak and are unable to think properly.

**Concept Applied**

- Apply concept of solubility of gases in liquid.

19. (c): When a non-volatile solute added to the volatile liquid, then partial pressure is only due to volatile component.
So, $p_{total} = p_{solvent}$

20. The liquid with a lower boiling point will vaporise first and has a higher vapour pressure. Hence, liquid $A$ will have a higher vapour pressure.

21. **Raoult's law :** For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p^\circ . x$
where, $p^\circ$ = vapour pressure of pure component
$x$ = mole fraction of that component

22. Henry's law : It states that partial pressure of a volatile liquid (or gas) in a liquid is directly proportional to its mole fraction.

$P \propto x \Rightarrow P = K_H x$ ($K_H$ = Henry's constant)

If we compare both equation, we can say that those are very similar and it seems that Raoult's law is a special case of Henry's law. When $K_H = P°$.

23. **Raoult's law :** For a solution of volatile liquids, the partial pressure of each component in the solution is directly proportional to its mole fraction. Thus, for any component, partial vapour pressure, $p \propto x \Rightarrow p = p°.\,x$
where, $p°$ = vapour pressure of pure component
$x$ = mole fraction of that component
Let a solution consists of two volatile liquids $A$ and $B$ with their mole fractions $x_A$ and $x_B$ respectively. If $p_A$ and $p_B$ are their partial vapour pressures,
then, $p_A \propto x_A \Rightarrow p_A = p_A^\circ x_A$ and $p_B \propto x_B \Rightarrow p_B = p_B^\circ x_B$
where $p_A^\circ$ and $p_B^\circ$ represent the vapour pressures of pure liquid components $A$ and $B$. $P_{total} = p_A + p_B$

Ideal solutions obey Raoult's law at all concentrations and temperature.

24. (c): $n$-Hexane and $n$-heptane will form an ideal solution.

25. A solution which obeys Raoult's law of vapour pressure for all compositions is called ideal solution.

For ideal solution $\Delta V_{mix} = 0$, $\Delta H_{mix} = 0$
$A-B$ interaction = $A-A$ and $B-B$ interactions.

26. (a) The differences between ideal solutions and non ideal solutions are as follows :
(i) In ideal solutions $\Delta V_{mix} = 0$ and $\Delta H_{mix} = 0$ whereas in non-ideal solutions,

$$\Delta V_{mix} \neq 0 \text{ and } \Delta H_{mix} \neq 0.$$

(ii) In ideal solutions, each component obeys Raoult's law at all temperatures and concentrations whereas in non ideal solutions, they do not obey Raoult's law.
(b) Given, weight of urea ($W_2$) = 30 g
Weight of water ($W_1$) = 846 g
Vapour pressure of water $p_1^\circ$ = 23.8 mm Hg

$$n_B = \frac{30}{60} = 0.5, \quad n_A = \frac{846}{18} = 47$$

$$\text{Mole fraction of water } (x_A) = \frac{n_A}{n_A + n_B}$$

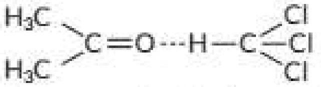
$$= \frac{47}{47 + 0.5} = \frac{47}{47.5} = 0.99$$

$p_A = p_A^\circ \times x_A = 23.8 \times 0.99 = 23.5$ mm Hg

27. (a): Acetone and chloroform form H-bonding due to which molecules come closer to each other and the volume of solution decreases.

28. A mixture of ethanol and acetone shows positive deviation from Raoult's law. When acetone is added to ethanol, some of the H-bonds between the ethanol molecules break down resulting in an increase in the vapour pressure of the mixture.

29. Mixture of chloroform and acetone shows negative deviation from Raoult's law, thus it forms maximum boiling azeotrope. This is because chloroform molecule is able to form hydrogen bond with acetone molecule as shown :



This decreases the escaping tendency of molecules of each component and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

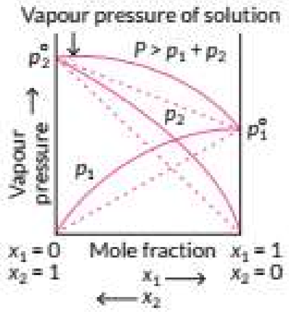
30. The differences between ideal solutions and non ideal solutions are as follows :
(i) In ideal solutions $\Delta V_{mix} = 0$ and $\Delta H_{mix} = 0$ whereas in non ideal solutions, $\Delta V_{mix} \neq 0$ and $\Delta H_{mix} \neq 0$.

(ii) In ideal solutions, each component obeys Raoult's law at all temperatures and concentrations whereas in non ideal solutions, they do not obey Raoult's law.

31. **Positive deviation :** For non-ideal solutions, if the vapour pressure is higher, than as expected from Raoult's law then it is said to exhibit positive deviation.

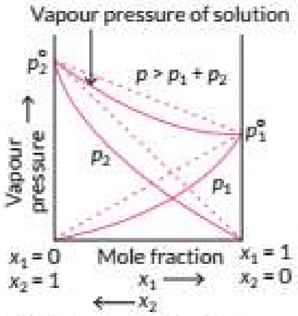
$A-B$ interactions are weaker than $A-A$ or $B-B$ interactions. Due to this, vapour pressure increases which results in positive deviation.

In positive deviation, intermolecular force decreases, volume increases, vapour pressures increases. enthalpy increases. Therefore, $\Delta H_{mix}$ = +ve, $\Delta V_{mix}$ = + ve. *e.g.*, ethanol + acetone and carbon disulphide + acetone show positive deviation.



Plot for non-ideal solution showing positive deviation

**Negative deviation :** For non-ideal solution, if the vapour pressure is lower than as expected from Raoult's law, then it is said to exhibit negative deviation. $A-B$ interactions are stronger than $A-A$ and $B-B$ interactions. Due to this, vapour pressure decreases which results in negative deviation. In negative deviation, intermolecular force increases, volume decreases, vapour pressure decreases and heat is released. Therefore, $\Delta H_{mix}$ = −ve, $\Delta V_{mix}$ = − ve. For example, phenol + aniline and chloroform + acetone show negative deviation.



Plot for non-ideal solution showing negative deviation

32. A mixture of ethanol and acetone shows positive deviation from Raoult's law. Pure ethanol possesses hydrogen bonding. Introduction of acetone between the molecules of ethanol results in breaking of some of these hydrogen bonds. Due to weakening of interactions, the solution shows positive deviation from Raoult's law.

33. (a): Solutions which show positive deviation from Raoult's law are minimum boiling azeotropes or have a lower boiling point than either of the two components.

34. Non-ideal solutions that show negative deviation from Raoult's law form maximum boiling azeotropes.

35. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phase and boil at constant temperature.

36. Mixture of chloroform and acetone shows negative deviation from Raoult's law, thus it forms maximum boiling azeotrope. This is because chloroform molecule is able to form hydrogen bond with acetone molecule as shown:

This decreases the escaping tendency of molecules of each component and consequently the vapour pressure decreases resulting in negative deviation from Raoult's law.

37. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phase and boil at constant temperature.

A minimum boiling azeotrope is formed by solutions showing a large positive deviation from Raoult's law at a specific composition. For example an ethanol-water mixture containing approximately 95% ethanol by volume.

38. Azeotropes are the binary mixtures of solutions that have the same composition in liquid and vapour phase and boil at constant temperature.

A maximum boiling azeotrope is formed by solutions showing a large negative deviation from Raoult's law at a specific composition.

For example, chloroform + acetone mixture.

39. The properties which depend upon the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are called colligative properties.

40. When a non-volatile solute is added to a solvent, the vapour pressure of the solvent decreases as compared to the vapour pressure of pure solvent.

41. $W_2 = 10$ g, $W_1 = 200$ g, $T = 308$ K

$P_A^\circ = 32$ mm Hg, $P_S = 31.84$ mm Hg, $M_1 = 18$, $M_2 = ?$

$$\frac{P_A^\circ - P_S}{P_A^\circ} = \frac{n_2}{n_1+n_2} = \frac{n_2}{n_1} \quad \text{(Solution is very dilute, } n_1+n_2=n_1\text{)}$$

$$\frac{32-31.84}{32} = \frac{10\times18}{M_2\times200}$$

$M_2 = 180$

42. (a) In osmotic pressure method, pressure can be measured at room temperature and the molarity of the solution is used instead of molality. That is why this method is used for determination of molar masses of macromolecules such as proteins as they are generally not stable at higher temperatures and polymers have poor solubility.

(b) Increase in temperature decreases the solubility of oxygen in water. As a result, amount of dissolved oxygen decreases. It becomes more difficult to breathe as oxygen is less. Hence, the aquatic species are not comfortable in warm water.

(c) $i$ for 1 M KCl = 2

$i$ for sugar solution = 1

$\therefore \Delta T_b = iK_b m = 2K_b$ (for KCl)

$\Delta T_b = K_b$ (for sugar)

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

43. Given, $P_s^\circ = 17.536$ mm, $P_s = ?$,

$w_2 = 20$ g, $M_2 = 180$ g mol$^{-1}$, $w_1 = 500$ g, $M_1 = 18$ g

$$\frac{P_s^\circ - P_s}{P_s^\circ} = x_2 = \frac{w_2/M_2}{w_1/M_1 + w_2/M_2}$$

$$\frac{17.536-P_s}{17.536} = \frac{\frac{20}{180}}{\frac{500}{18}+\frac{20}{180}} \approx \frac{\frac{20}{180}}{\frac{500}{18}} \qquad \left(\because \frac{20}{180} <<< \frac{500}{18}\right)$$

$$(17.536-P_s) = \frac{20}{180}\times\frac{18}{500}\times17.536 = 0.070$$

$P_s = 17.536 - 0.070 = 17.466$ mm

**Concept Applied**

- Relative lowering of vapour pressure of a solution is equal to mole fraction of solute, *i.e.*, $\frac{p^\circ - p_S}{p^\circ} = X_B$.

44. Given, weight of urea ($W_2$) = 30 g

Weight of water ($W_1$) = 846 g

Vapour pressure of water $p_1^\circ$ = 23.8 mm Hg

$$n_B = \frac{30}{60} = 0.5,\ n_A = \frac{846}{18} = 47$$

$$\text{Mole fraction of water } (x_A) = \frac{n_A}{n_A+n_B} = \frac{47}{47+0.5} = \frac{47}{47.5} = 0.99$$

$p_A = p_A^\circ \times x_A = 23.8 \times 0.99 = 23.5$ mm Hg

45. (a) Henry's law states that, the partial pressure of the gas in vapour phase ($p$) is proportional to the mole fraction of the gas ($x$) in the solution.

$p = K_H \cdot x$ where, $K_H$ = Henry's law constant. Different gases have different $K_H$ values at the same temperature.

Applications of Henry's law:

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

(ii) To minimise the painful effects of decompression sickness in deep sea divers, oxygen diluted with less soluble helium gas is used as breathing gas.

(b) Given, $w_2 = 5$ g, $w_1 = 95$ g, $P_s = 745$ mm

$P_s^\circ = 760$ mm, $M_2 = ?$

$$\frac{P_s^\circ - P_s}{P_s^\circ} = x_2 = \frac{n_2}{n_1+n_2} = \frac{w_1/M_2}{w_1/M_1 + w_2/M_2}$$

$$\frac{760-745}{760} = \frac{5/M_2}{95/18+5/M_2} = \frac{5/M_2}{95/18} \qquad \left(\because \frac{95}{18} >>> \frac{5}{M_2}\right)$$

$$\frac{15}{760}\times\frac{95}{18} = \frac{5}{M_2}$$

$$\Rightarrow \quad M_2 = \frac{5\times760\times18}{15\times95} = 48 \text{ g mol}^{-1}$$

**46.** **(c):** $\Delta T_b = K_b \times m$

$T_b - T_b^\circ = 0.52 \times 0.2 \Rightarrow T_b = 0.104 + T_b^\circ$

$T_b = (0.104 + 100)\,^\circ C = 100.104\,^\circ C$

**47.** **(c):** Assertion is correct but reason is wrong as elevation in boiling point is directly proportional to molality not molarity.

$\Delta T_b \propto m$

$\Delta T_b = K_b m$

**48.** Molal elevation constant may be defined as the elevation in boiling point when the molality of the solution is unity (*i.e.*, 1 mole of the solute is dissolved in 1 kg (1000 g) of the solvent). The units of $K_b$ are therefore, K/m or °C/m or K kg mol$^{-1}$.

**49.** The boiling point of the solution is always higher than that of the pure solvent. As the vapour pressure of the solution is lower than that of the pure solvent and vapour pressure increases with increase in temperature, hence, the solution has to be heated more to make the vapour pressure equal to the atmospheric pressure.

Elevation of boiling point is a colligative property because it depends on number of solute particles present in a solution.

**50.** **(d):** *X* represents freezing point of solution.

**51.** Molality ($m$) of urea $= \dfrac{7.5 \times 1000}{60 \times 100} = 1.25$ m ...(i)

Molality of substance,

$Z = \dfrac{42.75 \times 1000}{\text{Molar mass} \times 100} = \dfrac{427.5}{\text{Molar mass}}$ ...(ii)

As both the solutions have same depression in freezing point so they have same molality.

From eqn. (i) and (ii), we get

$1.25 = \dfrac{427.5}{\text{Molar mass}}$

Molar mass of $Z$ = 342 g/mol

**52.** Mass of glucose ($C_6H_{12}O_6$), $W_2 = 60$ g

Mass of water, $W_1 = 250$ g

$M_2$ (Mol. mass of $C_6H_{12}O_6$) = 180 g mol$^{-1}$

$K_f = 1.86$ K kg mol$^{-1}$, $T_f = ?$

Using formula, $\Delta T_f = K_f \times \dfrac{W_2 \times 1000}{M_2 \times W_1} = 1.86 \times \dfrac{60 \times 1000}{180 \times 250}$ K

$\Delta T_f = T_f^\circ - T_f$ or $T_f = T_f^\circ - \Delta T_f = 273 - 2.48 = 270.52$ K

**Key Points**

- As there is depression in freezing point so,
  $T_f < T_f^\circ \quad \therefore \quad \Delta T_f = T_f^\circ - T_f = +\text{ve}$

**53.** Given : $W_2 = ?$, $M_2 = 256$ g mol$^{-1}$, $\Delta T_f = 0.48$ K

$W_1 = 75$ g, $K_f = 5.12$ K kg mol$^{-1}$

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

$W_2 = \dfrac{\Delta T_f \times M_2 \times W_1}{K_f \times 1000} = \dfrac{0.48 \times 256 \times 75}{5.12 \times 1000} = 1.8$ g

**54.** Mass of ethylene glycol ($C_2H_6O_2$), $W_2 = 31$ g

Mass of water, $W_1 = 600$ g

$M_2$ (Mol. mass of $C_2H_6O_2$) = 62 g mol$^{-1}$,

$K_f = 1.86$ K kg mol$^{-1}$, $T_f = ?$

Using formula, $\Delta T_f = K_f \times \dfrac{W_2 \times 1000}{M_2 \times W_1}$

$= 1.86 \times \dfrac{31 \times 1000}{62 \times 600}$ K $= 1.55$ K

$\Delta T_f = T_f^\circ - T_f$ or $T_f = T_f^\circ - \Delta T_f = 273 - 1.55 = 271.45$ K

**55.** Given, $M_2 = 176$ g mol$^{-1}$, $\Delta T_f = 1.5$°C

$w_1 = 75$ g, $K_f = 3.9$ K kg mol$^{-1}$, $w_2 = ?$

$\Delta T_f = \dfrac{K_f \times w_2 \times 1000}{M_2 \times w_1}$

$w_2 = \dfrac{\Delta T_f \times M_2 \times w_1}{K_f \times 1000} = \dfrac{1.5 \times 176 \times 75}{3.9 \times 1000} = 5.077$ g

**56.** Molality of sucrose solution ($m$) $= \dfrac{w_2 \times 1000}{M_2 \times w_1}$

$= \dfrac{4 \times 1000}{342 \times 96} = 0.121$ m

$\Delta T_f$ for sucrose solution = 273.15 − 271.15 = 2 K

$K_f = \dfrac{\Delta T_f}{m} = \dfrac{2}{0.121} = 16.52$ K/m

Molality of glucose solution $= \dfrac{5 \times 1000}{180 \times 95} = 0.292$ m

$\Delta T_f = K_f \times m = 16.52 \times 0.292 = 4.82$ K

Freezing point of glucose solution = 273.15 − 4.82
= 268.33 K

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

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

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

**58.** Molality of sugar solution

$= \dfrac{W_2 \times 1000}{M_2 \times W_1} = \dfrac{5}{342} \times \dfrac{1000}{95} = 0.154$ m

$\Delta T_f = T_f^\circ - T_f = 273.15 - 271 = 2.15$ K

$\Delta T_f = K_f \times m \quad \therefore \; K_f = \dfrac{\Delta T_f}{m} = \dfrac{2.15}{0.154}$

Molality of glucose solution

$= \dfrac{W_2 \times 1000}{M_2 \times W_1} = \dfrac{5}{180} \times \dfrac{1000}{95} = 0.292$ m

$\therefore \quad \Delta T_f$ (Glucose) $= K_f \times m = \dfrac{2.15}{0.154} \times 0.292 = 4.08$ K

$\therefore$ Freezing point of glucose solution = 273.15 − 4.08
= 269.07 K

**59.** Molality ($m$) of sucrose solution

$= \dfrac{w_2 \times 1000}{M_2 \times w_1} = \dfrac{10}{342} \times \dfrac{1000}{90} = 0.325$ m

$\Delta T_f$ for sucrose solution $= T_f^\circ - T_f = (273.15 - 269.15)$ K = 4 K

$\therefore \; K_f = \dfrac{\Delta T_f}{m} = \dfrac{4 \text{ K}}{0.325 \text{ m}} = 12.308$ K/m $\because \Delta T_f = K_f \times m$

Molality of glucose solution $= \dfrac{10}{180} \times \dfrac{1000}{90} = 0.617$ m

$\Delta T_f = K_f \times m$

$\therefore \quad \Delta T_f = 12.308$ K/m $\times$ 0.617 m = 7.59 = 7.6 K

∴ Freezing point of glucose solution,

$T_f^o - \Delta T_f = (273.15 - 7.60)\text{ K} = 265.55\text{ K}$

60. Mass of ethylene glycol ($C_2H_6O_2$), $W_2 = 31$ g
Mass of water, $W_1 = 500$ g
$M_2$ (Mol. mass of $C_2H_6O_2$) = 62 g mol$^{-1}$,
$K_f = 1.86$ K kg mol$^{-1}$, $T_f$ = ?

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

$$= 1.86 \times \frac{60 \times 1000}{180 \times 250}\text{K}$$

$\Delta T_f = T_f^\circ - T_f$ or $T_f = T_f^\circ - \Delta T_f = 273 - 2.48 = 270.52\text{K}$

61. $T_f = -15°\text{C}$, $K_f = 1.86$ K kg mol$^{-1}$

$\Delta T_f = T_f^\circ - T_f = 0 - (-15°\text{C}) = 15°\text{C}$

$\Delta T_f = K_f \times m$

$15 = 1.86 \times \frac{\text{Number of moles of solute}}{5}$

⇒ Number of moles of solute = 40.32 moles

$\Delta T_b = K_b \times m$

$\Delta T_b = 0.52 \times \frac{\text{Moles of solute}}{\text{Mass of solvent (kg)}}$

$\Delta T_b = 0.52 \times \frac{40.32}{5\text{kg}} = 4.19$

$\Delta T_b = T_b - T_b^\circ \Rightarrow 4.19 = T_b - 373$

$T_b = 373 + 4.19 = 377.19\text{ K}$

**Key Points**

- Same moles of solute are used here for the calculation of boiling point and freezing point.

62. (a): In osmotic pressure method, pressure can be measured at room temperature and the molarity of the solution is used instead of molality. That is why this method is used for determination of molar masses of macromolecules such as proteins as they are generally not stable at higher temperatures and polymers have poor solubility.

63. (c): A raw mango shriveled into pickle due to osmosis.

64. (a): Colligative properties of ideal solutions depend only on the number of particles of solute dissolved in a definite amount of the solvent and do not depend on the nature of solute.

**Answer Tips**

- $\pi = CRT$ where $C$ is Molarity.

65. When the external pressure applied becomes more than the osmotic pressure of solution then the solvent molecules from the solution pass through the semi-permeable membrane to the solvent side and the process is called reverse osmosis.

66. In osmotic pressure method, pressure can be measured at room temperature and the molarity of the solution is used instead of molality. That is why this method is used for determination of molar masses of macromolecules such as proteins as they are generally not stable at higher temperatures and polymers have poor solubility.

67. Osmotic pressure is the extra pressure which is applied on the solution to prevent the flow of solvent into the solution through a semi-permeable membrane.

68. Two solutions having same osmotic pressure at a given temperature are called isotonic solutions.

69. Molarity ($M$) of urea solution

$$= \frac{w \times 1000}{M \times \text{Volume of solvent (mL)}} = \frac{5 \times 1000}{60 \times 100} = 0.833\text{M}$$

Osmotic pressure ($\pi$) = $CRT = 0.833 \times 0.0821 \times 300$
= 20.51 atm

70. (a) When we cook the food inside the pressure cooker, high pressure is created inside the cooker. Pressure will increase so, the boiling point will increase. Thus, cooking is faster in pressure cooker than in cooking pan.

(b) When red blood cells (RBC) are placed in saline water, water will flow out of the cells (low conc. to high conc.) and they would shrink. Such a solution is called hypertonic. On the other hand when red blood cells (RBC) are placed in distilled water, water will flow into the cell and they would swell. Such solution is called hypotonic.

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

(ii) When the external pressure applied becomes more than the osmotic pressure of solution then the solvent molecules from the solution pass through the semi-permeable membrane to the solvent side and the process is called reverse osmosis.

72. (i) 1.2% sodium chloride solution is hypertonic with respect to 0.9% sodium chloride solution or blood cells thus, on placing blood cells in this solution exosmosis takes place that results in shrinking of cells.

(ii) 0.4% sodium chloride solution is hypotonic with respect to 0.9% sodium chloride solution or blood cells thus, on placing blood cells in this solution endosmosis takes place that results in swelling of cells.

**Concept Applied**

- **Exosmosis :** The outward flow of solvent (water) from the cell when placed in more concentrated solution (hypertonic). Cell shrinks in this case.
- **Endosmosis :** The inflow of solvent (water) into a cell from outside when cell is placed in distilled water. Cell swells up in this case.

73. $\pi = cRT$, $c = \frac{w_2}{M_2 \times V}$

$w_2$ = weight of solute
$M_2$ = molar mass of solute

$\frac{\pi_1}{\pi_2} = \frac{c_1RT_1}{c_2RT_2}$. Given, $T_1 = T_2$

$$\frac{\pi_1}{\pi_2}=\frac{c_1}{c_2} \Rightarrow \frac{4.98}{1.52}=\frac{\frac{30}{180\times 1}}{c_2} \Rightarrow c_2=\frac{30\times 1.52}{180\times 4.98}=0.051 \text{ mol/L}$$

74. Mass of urea = 15 g
Molar mass of urea = 60 g $\text{mol}^{-1}$
Molar mass of glucose = 180 g $\text{mol}^{-1}$
Mass of glucose = ?
For isotonic solution, osmotic pressure, $\pi_{1(\text{urea})} = \pi_{2(\text{glucose})}$
$n_1 = n_2$ (when volume is same)

or $$\frac{W_1}{M_1}=\frac{W_2}{M_2} \Rightarrow \frac{15}{60}=\frac{W_2}{180} \Rightarrow W_2=\frac{15\times 180}{60}=45 \text{ g}$$

**Answer Tips**

- $\pi = cRT = \frac{n}{V\,(\text{in L})}RT = \frac{W}{M\times V\,(\text{in L})}\times RT$

75. (i) Osmotic pressure is the extra pressure which is applied on the solution to prevent the flow of solvent into the solution through a semi-permeable membrane.
(ii) Properties which depend upon the number of solute particles irrespective of their nature relative to the total number of particles present in the solution are called colligative properties.

76. **van't Hoff factor :** It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i=\frac{\text{Experimental (or observed) value of colligative property}}{\text{Calculated (or normal) value of colligative property}}$$

77. The molar mass which is either lower or higher than the expected or normal value is known as abnormal molar mass.

78. (a) When $i > 1$, solute is in dissociated state in the solution.
(b) When $i < 1$, solute is in associated state in the solution.

79. **van't Hoff factor :** It is defined as the ratio of the experimental value of colligative property to the calculated value of the colligative property and is used to find out the extent of dissociation or association. Mathematically, it is represented as

$$i=\frac{\text{Experimental (or observed) value of colligative property}}{\text{Calculated (or normal) value of colligative property}}$$

(i) van't Hoff factor ($i$) > 1 for solutes undergoing dissociation
(ii) van't Hoff factor ($i$) < 1 for solutes undergoing association

80. $i$ for 1 M KCl = 2
$i$ for sugar solution = 1
$\therefore$ $\Delta T_b = iK_b m = 2K_b$ (for KCl)
$\Delta T_b = K_b$ (for sugar)
$\therefore$ $\Delta T_b$ of 1 M KCl solution is double than that of 1 M sugar solution.

81. (i) As KCl is an electrolyte and one formula unit of KCl dissociates to give two ions ($K^+$ and $Cl^-$), therefore molar concentration of particles in the solution = 0.1 × 2 M = 0.2 M

As elevation of boiling point (or any colligative property) is directly proportional to number of particles in solution, hence 0.1 M KCl has higher boiling point than that 0.1 M glucose.
(ii) Salting is used because most bacteria, fungi and other potentially pathogenic organisms cannot survive in a highly salty environment, due to the hypertonic nature of salt. Any living cell in such an environment will become dehydrated through osmosis and die or become temporarily deactivated.

**Key Points**

- High concentration of salt - Hypertonic
- Low concentration of salt - Hypotonic

82. (a) $i$ for 0.1 m KCl = 2
$i$ for 0.1 m glucose = 1
$\therefore$ $\Delta T_b = i\,K_b m = 2K_b \times 0.1$ (for KCl)
$\Delta T_b = 1K_b \times 0.1$ (for glucose)
Thus, $\Delta T_b$ for KCl will be higher than for glucose solution as KCl will undergo dissociation and $i$ is greater than 1.
(b) (i) $i$ will be greater than 1 when $CH_3COOH$ is dissolved in water as it undergoes dissociation.
$$CH_3COOH + H_2O \longrightarrow CH_3COO^- + H_3O^+$$
(ii) $i$ will be less than 1 when $CH_3COOH$ is dissolved in benzene as it undergoes association.
$$2CH_3COOH \xrightarrow{\text{benzene}} (CH_3COOH)_2 \quad \text{(Dimerisation)}$$

83. Mass of $CaCl_2$ ($W_2$) = 10 g
Mass of water ($W_1$) = 200 g
Molar mass of $CaCl_2$ ($M_2$) = 111 g $\text{mol}^{-1}$
Molal elevation constant ($K_b$) = 0.52 K kg $\text{mol}^{-1}$
$$m=\frac{W_2\times 1000}{M_2\times W_1} \Rightarrow m=\frac{10}{111}\times\frac{1000}{200}=0.450 \text{ m}$$
$\Delta T_b = iK_b m = 3 \times 0.52 \times 0.450 = 0.702$ K

84. $W_2 = 4$ g, $M_2 = 120$ g $\text{mol}^{-1}$
$W_1 = 100$ g, $K_b = 0.52$ K kg $\text{mol}^{-1}$
For complete dissociation, $i = 2$
Using formula, $\Delta T_b = iK_b m$

or $$\Delta T_b=\frac{i\times K_b\times W_2\times 1000}{M_2\times W_1}=2\times 0.52\times\frac{4\times 1000}{120\times 100}=0.34 \text{ K}$$
$\therefore$ $T_b = T_b^\circ + \Delta T_b = 100 + 0.34 = 100.34°C$

85. (i) The boiling point of 1M NaCl solution is more than that of 1M glucose solution as the value of '$i$', *i.e.*, van't Hoff factor is 2 for NaCl and it is 1 for glucose. Also,
$$\Delta T_b = i \times K_b \times m$$
Hence, from the above mathematical reaction, it is clear that the increase in boiling point will be more for NaCl than that of glucose.
(ii) Let $p^\circ$ be the vapour pressure of pure benzene. The vapour pressure of the solution will be $\frac{90}{100}p^\circ = 0.9p^\circ$.
Molar mass of solute ($M_2$) and benzene ($M_1$) are 50 g $\text{mol}^{-1}$ and 78.1 g $\text{mol}^{-1}$ respectively. Mass of benzene ($w_1$) is 78 g.
$$\frac{p^\circ - p}{p^\circ}=\frac{w_2}{M_2}\times\frac{M_1}{w_1}$$

$$\frac{p^\circ - 0.9p^\circ}{p^\circ} = \frac{w_2}{50} \times \frac{78.1}{78}$$

$\Rightarrow w_2 = 5$ g

Thus, the mass of X dissolved in the solution is 5 g.

(iii) It is given that $MgCl_2$ is completely dissociated in the solution.

$$MgCl_{2(s)} \xrightarrow{(aq)} Mg^{2+}_{(aq)} + 2Cl^-_{(aq)}$$

$\therefore$ $i = 3$, $w_B = 10$ g; $w_A = 200$ g $= 0.2$ kg

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

$$\Delta T_b = i \times K_b \times m = \frac{i \times K_b \times w_B}{M_B \times w_A}$$

$$\Delta T_b = \frac{(3) \times (0.512 \text{ K kg mol}^{-1}) \times (10 \text{g})}{(95 \text{ g mol}^{-1}) \times (0.2 \text{ kg})} = 0.80 \text{ K}$$

**86.** **(d):** $NaCl \longrightarrow Na^+ + Cl^-$ $i = 2$

$Na_2SO_4 \longrightarrow 2Na^+ + SO_4^{2-}$ $i = 3$

$C_6H_{12}O_6$ (non-ionisable) $i = 1$

$Al_2(SO_4)_3 \longrightarrow 2Al^{3+} + 3SO_4^{2-}$ $i = 5$

Greater the number of ions produced on dissociation, greater is the van't Hoff factor.

$\because$ $\Delta T_f \propto i$

$\therefore$ $Al_2(SO_4)_3$ shows largest freezing point depression.

**87.** Molecular mass of Glauber's salt ($Na_2SO_4 \cdot 10H_2O$)

$= [2 \times 23 + 32 + 16 \times 4 + 10 \times (2 \times 1 + 16)]$

$= (46 + 32 + 64 + 180)$ g $mol^{-1}$ $= 322$ g $mol^{-1}$

$Na_2SO_4 \cdot 10H_2O$ ionises as :

$$Na_2SO_4 \cdot 10H_2O \rightleftharpoons 2Na^+ + SO_4^{2-} + 10H_2O$$

$\Rightarrow$ $i = 3$

$$m = \frac{n_B}{W_A} = \frac{W_B}{M_B \times W_A} = \frac{6.00 \text{ g}}{322 \text{ g mol}^{-1} \times 0.1 \text{ kg}}$$

$$= 0.186 \text{ mol kg}^{-1} = 0.186 \text{ m}$$

Also, $\Delta T_f = i K_f \cdot m = 3 \times 1.86 \text{ K m}^{-1} \times 0.186 \text{ m} = 1.04$ K

$\Rightarrow$ $T_f = T_f^o - \Delta T_f$

$= (273 - 1.04)$ K $= 271.96$ K

**88.** Given : $W_2 = 19.5$ g, $W_1 = 500$ g, $K_f = 1.86$ K kg $mol^{-1}$

$\Delta T_{f(obs)} = 1.0$ K

$$\therefore \quad M_{2(obs)} = \frac{1000 \times K_f \times W_2}{W_1 \times \Delta T_{f(obs)}} = \frac{1000 \times 1.86 \times 19.5}{500 \times 1}$$

$$= 72.54 \text{ g mol}^{-1}$$

$M_{2(cal)}$ for F—$CH_2$—COOH = 78 g $mol^{-1}$

$$i = \frac{M_{2(cal)}}{M_{2(obs)}} = \frac{78}{72.54} = 1.0753$$

| | F—$CH_2$—COOH | $\rightleftharpoons$ F—$CH_2$—$COO^-$ | + $H^+$ |
|---|---|---|---|
| Initial moles | C | 0 | 0 |
| Moles at eqm. | C − Cα | Cα | Cα |

Total no. of moles = C − Cα + Cα + Cα = C(1 + α)

$$i = \frac{C(1+\alpha)}{C} = 1 + \alpha$$

or $\alpha = i - 1 = 1.0753 - 1 = 0.0753 = 7.53\%$

**Answer Tips**

- Since $\Delta T$ is the difference between values of temperatures, it is independent of the unit it is measured in *i.e.*, $\Delta T = 1°C = 1$ K.

**89.** Given, $W_2 = 5$ g, $M_2 = 122$ g $mol^{-1}$, $W_1 = 35$ g

$\Delta T_f = 2.94$ K, $K_f = 4.9$ K kg $mol^{-1}$

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

or $2.94 = i \times 4.9 \times \frac{5 \times 1000}{122 \times 35}$ or $i = 0.512$

As $i < 1$, solute is associated.

| | $2C_6H_5COOH$ | $\rightleftharpoons (C_6H_5COOH)_2$ |
|---|---|---|
| Initial moles | 1 | 0 |
| Moles at eqm. | 1 − α | α/2 |

Total no. of moles after association : 1 − α + α/2 = 1 − α/2

$$\therefore \quad i = \frac{1 - \alpha/2}{1} = 1 - \frac{\alpha}{2}$$

$$\Rightarrow \quad 1 - \frac{\alpha}{2} = 0.512$$

or $\alpha = 2 \times (1 - 0.512) = 0.976$ or 97.6%

**Concept Applied**

- For association of solute, $i = 1 - \alpha + \frac{\alpha}{n}$

  here $n = 2$, so, $i = 1 - \frac{\alpha}{2}$

**90.** Given, $\Delta T_f = 0.068°C$ or 0.068 K

$m = 0.01$ M, $K_f = 1.86$ K kg $mol^{-1}$

$\Delta T_f = iK_f \cdot m$

$\Rightarrow$ $0.068 = i \times 1.86 \times 0.01$

$$\Rightarrow \quad i = \frac{0.068}{1.86 \times 0.01} = 3.65$$

$AlCl_3$ dissociates as

| | $AlCl_3$ | $\rightleftharpoons Al^{3+}$ | + $3Cl^-$ |
|---|---|---|---|
| Initially | 1 | 0 | 0 |
| At eqm. | 1 − α | α | 3α |

Total no. of moles after dissociation = 1 − α + α + 3α = 1 + 3α

$$i = \frac{1 + 3\alpha}{1} = 3.65$$

$\Rightarrow$ $1 + 3\alpha = 3.65 \Rightarrow 3\alpha = 3.65 - 1 = 2.65$

$$\Rightarrow \quad \alpha = \frac{2.65}{3} = 0.883$$

Percentage association = 88.3%

**91.** $\Delta T_f = iK_f \cdot m$

$i$ for $MgCl_2 = 3$

$$\text{Molality, } m = \frac{W_2 \times 1000}{M_2 \times W_1} = \frac{1.9 \times 1000}{95 \times 50} = 0.4 \text{ m}$$

$\Delta T_f = 3 \times 1.86 \times 0.4 = 2.232$ K

Freezing point of solution, $T_f = T_f^o - \Delta T_f = 273 - 2.232$ K

$= 270.77$ K

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

$K_f = 3.83$ K kg $mol^{-1}$, $\Delta T_f = K_f \times m$

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

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

$\because \quad i = \dfrac{\text{Normal atomic mass}}{\text{Observed atomic mass}} = \dfrac{32}{256} = \dfrac{1}{8}$

Sulphur exists as $S_x$ *i.e.*, $S_8$.

**Concept Applied**

- Value of observed atomic mass is used to calculate the value of *x* here.

93. $W_2 = 3.9$ g, $W_1 = 49$ g, $\Delta T_f = 1.62$ K, $M_2 = 122$ g mol$^{-1}$, $K_f = 4.9$ K kg mol$^{-1}$

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

$$\Rightarrow \quad 1.62 = \frac{i \times 4.9 \times 3.9 \times 1000}{122 \times 49} \Rightarrow i = \frac{1.62 \times 122 \times 49}{4.9 \times 3.9 \times 1000} = 0.506$$

As $i < 1$, solute is associated.

94. $\Delta T_f = iK_f m = \dfrac{i \times K_f \times W_2 \times 1000}{M_2 \times W_1}$

$$2 = \frac{2 \times 1.86 \times W_2 \times 1000}{58.5 \times 37.2} \Rightarrow W_2 = 1.17 \text{ g}$$

95. (a) The differences between ideal solutions and non-ideal solutions are as follows :

(i) In ideal solutions $\Delta V_{mix} = 0$ and $\Delta H_{mix} = 0$ whereas in non ideal solutions, $\Delta V_{mix} \neq 0$ and $\Delta H_{mix} \neq 0$.

(ii) In ideal solutions, each component obeys Raoult's law at all temperatures and concentrations whereas in non ideal solutions, they do not obey Raoult's law.

(b) $\Delta T_f = iK_f m = \dfrac{i \times K_f \times W_2 \times 1000}{M_2 \times W_1}$

$$2 = \frac{2 \times 1.86 \times W_2 \times 1000}{58.5 \times 100} \Rightarrow W_2 = 3.145 \text{ g}$$

96. (a) The two characteristics of non-ideal solution are :

(i) They do not obey Raoult's law over the entire range of concentration.

(ii) The vapour pressure of non-ideal solution is either higher or lower than that predicted by Raoult's law.

(b) Given, $w_2 = 2$ g, $M_2 = 122$ g mol$^{-1}$, $w_1 = 25$ g,

$\Delta T_f = 1.62$ K, $K_f = 4.9$ kg mol$^{-1}$

$\Delta T_f = i\,K_f m$

$$1.62 = i \times 4.9 \times \frac{2}{122 \times 25} \times 1000$$

$$\Rightarrow \quad i = \frac{1.62 \times 122 \times 25}{4.9 \times 2 \times 1000} = 0.5042$$

$$\alpha_{\text{association}} = \frac{1-i}{1-\frac{1}{n}} = \frac{1-0.5042}{1-\frac{1}{2}} = 0.4958 \times 2 = 0.9916$$

% of association = 0.9916 × 100 = 99.16%

97. $\pi = iCRT = i \cdot \dfrac{n}{V}RT = i \times \dfrac{w}{M} \times \dfrac{1}{V}RT$

or $\quad 4.75 = i \times \dfrac{5.85}{58.5} \times \dfrac{1}{1} \times 0.082 \times 300$ or $i = 1.93$

$$\begin{array}{lccc} & \text{NaCl} & \longrightarrow \text{Na}^+ & + \ \text{Cl}^- \\ \text{Initial moles} & C & 0 & 0 \\ \text{Moles at eqm.} & C - C\alpha & C\alpha & C\alpha \end{array}$$

Total no. of moles = $C(1 + \alpha)$

$i = \dfrac{C(1+\alpha)}{C}$ or $i = 1 + \alpha$ or $1 + \alpha = 1.93$

or $\quad \alpha = 0.93$ or 93%

**Concept Applied**

- For dissociation, $i = 1 - \alpha + x\alpha + y\alpha$
  for NaCl, $x = 1$, $y = 1$ so, $i = 1 + \alpha$

98. Given : $\alpha = 95\%$, $C = 0.1$ M, $T = 27°C = 300$ K,
$R = 0.0821$ L atm K$^{-1}$ mol$^{-1}$

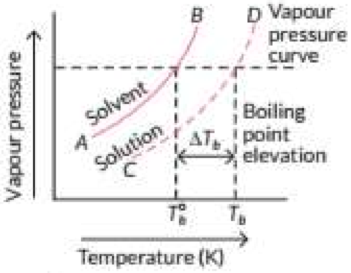
For $Na_2SO_4$, $\alpha_{\text{dissociation}} = \dfrac{i-1}{n-1}$

$$\frac{95}{100} = \frac{i-1}{3-1} \Rightarrow i = 2.9$$

$\pi = i\,CRT$

$\pi = 2.9 \times 0.1 \times 0.0821 \times 300 = 7.14$ atm

99. (a) Let $T_b^\circ$ is the boiling point of pure solvent and $T_b$ is the boiling point of solution. The increase in the boiling point, $\Delta T_b = T_b - T_b^\circ$ is known as elevation of boiling point.



(b) Given, $W_2 = 25$ mg $= 25 \times 10^{-3}$ g
$M_2 = (2 \times 39) + 32 + (4 \times 16) = 174$ g mol$^{-1}$,
$i = 3$, $V = 2$L, $T = 25°C = 25 + 273 = 298$ K

$$\pi = i\,CRT = 3 \times \frac{25 \times 10^{-3}}{174 \times 2} \times 0.0821 \times 298 = 5.27 \times 10^{-3} \text{ atm}$$

100. (i) The value of van't Hoff factor for ethanoic acid in benzene is close to 0.5 as two molecules of ethanoic acid associate to form a dimer in benzene solution.

$2CH_3COOH \rightleftharpoons (CH_3COOH)_2$

$$i = \frac{\text{Number of solute particles in solution}}{\text{Theoretical number of solute particles}}$$

$$= \frac{1}{2} = 0.5$$

(ii) It has been given that $K_2SO_4$ is completely dissociated. When $K_2SO_4$ is dissolved in water, $K^+$ and $SO_4^{2-}$ ions are produced as shown:

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

Total number of ions produced = 3

$\therefore \quad i = 3$

Given,

$w = 2.32 \times 10^{-2}$ g; $V = 2$ L; $R = 0.082$ L atm K$^{-1}$ mol$^{-1}$
$T = 25°C = (25 + 273)$ K $= 298$ K

Molar mass of $K_2SO_4 = (2 \times 39) + (1 \times 32) + (4 \times 16)$
$= 174$ g mol$^{-1}$

Applying the following relation,

$$\pi = i\frac{n}{V}RT$$

$$= i \times \frac{w}{M} \times \frac{1}{V}RT$$

$$= 3 \times \frac{2.32 \times 10^{-2}}{174} \times \frac{1}{2} \times 0.082 \times 298$$

$= 4.8 \times 10^{-3}$ atm

(iii) $\Delta T_f = iK_f m$

$$\Rightarrow \quad 0.512 = \frac{i \times 5.12 \times 25.6 \times 1000}{32 \times 1000}$$

$$\Rightarrow \quad i = \frac{0.512 \times 32 \times 1000}{5.12 \times 25.6 \times 1000}$$

$$i = \frac{1}{8} = 0.125$$

As '$i$' is less than 1, therefore S is associated, *i.e.*, 8 moles of S are associated as shown $8S \leftrightarrow S_8$.
Therefore, the molecular formula of sulphur is $S_8$.

## CBSE Sample Questions

1. (c): Molarity is a mean to express concentration of solution. It is not a colligative property. **(0.77)**

2. (b): According to Le-Chatelier principle, solubility of gases in liquids decreases with rise in temperature because dissolution is an exothermic and reversible process. **(0.77)**

3. (b): Aquatic species are more comfortable in cold water rather than in warm water because the amount of dissolved oxygen in water decreases with rise in the water's temperature. **(1)**

4. (a) Henry's law : The partial pressure of the gas in vapour phase ($p$) is proportional to the mole fraction of the gas ($x$) in the solution. **(1)**

$p = K_H x$

The pressure underwater is high, so the solubility of gases in blood increases. When the diver comes to surface, the pressure decreases and so does the solubility, causing bubbles of nitrogen in blood. To avoid this situation and maintain the same partial pressure of nitrogen underwater too, the dilution is done. **(1)**

(b) Using equation $p = K_H \times x$

Mole fraction of argon in water, $x = p/K_H = 6/40 \times 10^3$

$= 1.5 \times 10^{-4}$ **(1)**

5. (b): Raoult's law **(0.77)**

6. (c): Let $y_B$ be mole fraction of benzene in vapour phase.
$y_T$ = Mole fraction of toluene in vapour phase.

$$y_{\text{Benzene}} = \frac{p_{\text{Benzene}}}{p_{\text{Total}}}\ ;\ y_{\text{Toluene}} = \frac{p_{\text{Toluene}}}{p_{\text{Total}}}$$

$p_{\text{Benzene}} = p^{\circ}_{\text{Benzene}}(x_{\text{Benzene}})$, $p_{\text{Toluene}} = p^{\circ}_{\text{Toluene}}(x_{\text{Toluene}})$

Since, $p^{\circ}_{\text{Benzene}} > p^{\circ}_{\text{Toluene}}$, $p_{\text{Benzene}} > p_{\text{Toluene}}$

Hence, $y_{\text{Benzene}} > y_{\text{Toluene}}$ **(1)**

7. (b): Nitric acid and water form maximum boiling azeotrope because they show large deviation from Raoult's law due to hydrogen bonding. **(1)**

8. (a): Fluid inside blood cells is isotonic with 0.9% NaCl solution. Hence, it will shrink when placed in water containing more than 0.9% (mass/volume) NaCl solution. **(0.77)**

9. (a): $\Delta T_f = T_f^{\circ} - T_f = 0 - (-14) = 14°\text{C}$, $\Delta T_f = K_f m$

$$\Delta T_f = K_f \times \frac{n_2 \times 1000}{w_1}$$

$$14 = 1.86 \times \frac{n_2 \times 1000}{1000} \Rightarrow n_2 = 7.5 \text{ mol}$$ **(0.77)**

10. (c) **(0.77)**

11. (c): Cryoscopic constant varies with type of solvent hence is not a universal constant. **(1)**

12. Given : $K_b = 0.52$ K kg mol$^{-1}$, boiling point of glucose, $\Delta T_b = 101.04°\text{C}$

As $\Delta T_b = T_b - T_b^{\circ} = 101.04°\text{C} - 100°\text{C} = 1.04°\text{C}$

$\Delta T_b = K_b m$

$$m = \frac{\Delta T_b}{K_b} = \frac{1.04}{0.52} = 2$$ **(1)**

According to Raoult's law,
Relative lowering of vapour pressure = $x_B$
where $x_B$ is mole fraction of solute.
Moles of glucose, $n_2 = 2$

$$\text{Moles of water, } n_1 = \frac{1000}{18} = 55.56$$

$$\therefore \quad \text{Relative lowering of vapour pressure} = \frac{n_2}{n_2 + n_1}$$ **(1/2)**

$$= \frac{2}{2 + 55.56} = \frac{2}{57.56} = 0.034$$ **(1/2)**

13. The melting point of ice is the freezing point of water. We can use the depression in freezing point property in this case.

(a) In 3rd reading for 0.5 g, there has to be an increase in depression of freezing point and therefore, decrease in freezing point *i.e.*, decrease in melting point, when amount of salt is increased but the trend is not followed in this case. **(1)**

(b) Two sets of reading help to avoid error in data collection and give more objective data. **(1)**

(c) $$\Delta T_f(\text{glucose}) = 1 \times K_f \times \frac{0.6 \times 1000}{180 \times 10}$$

$$\Delta T_f(\text{NaCl}) = 2 \times K_f \times \frac{0.6 \times 1000}{58.5 \times 10}$$

$$\Rightarrow \quad 3.8 = 2 \times K_f \times \frac{0.6 \times 1000}{58.5 \times 10}$$ **(1)**

Dividing (i) by (ii)

$$\frac{\Delta T_f\ (\text{glucose})}{3.8} = \frac{58.5}{2 \times 180}$$

$\Rightarrow \quad \Delta T_f = 0.62$

$\therefore \quad T_f = -0.62$ °C **(1)**

**OR**

Depression in freezing point is directly proportional to molality (mass of solute when the amount of solvent remains same).

0.3 g of salt causes depression of 1.9 °C.
0.6 g of salt causes depression of 3.8 °C.
1.2 g of salt causes depression of 3.8 × 2 = 7.6 °C. **(2)**