DPP-7 [Elevation in Boiling Point] – SOLUTIONS

Chapter: Solution

"I accept Class 12 fully. No excuses. No delay. I will complete every assignment honestly. I will work without waiting for motivation. This is my year. I will not waste it.."

TYPE–1 : Conceptual & Definition Based

1. **The molal elevation constant is the ratio of the elevation in B.P. to :**
2. Molarity
3. Molality
4. Mole fraction of solute
5. Mole fraction of solvent

Explanation

Molal Elevation Constant (K_b) is also called **Ebullioscopic Constant**.
It is defined as the elevation in boiling point when 1 mole of non-volatile solute is dissolved in 1 kg of solvent.
Formula: $\Delta T_b = K_b \times m$ (where m = molality)
Therefore: $K_b = \dfrac{\Delta T_b}{m} = \dfrac{\text{Elevation in B.P.}}{\text{Molality}}$

Approach

Think of K_b as the "sensitivity" of a solvent to boiling point changes:

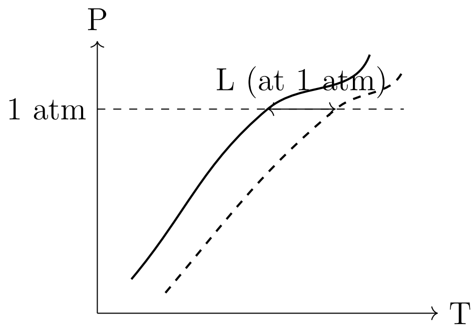
- Higher K_b → More sensitive → Larger ΔT_b for same molality
- K_b depends ONLY on the solvent, not the solute!

The formula $\Delta T_b = K_b \times m$ shows that K_b is the ratio of elevation to molality.

Answer

Option (2) Molality
$K_b = \dfrac{\Delta T_b}{\text{Molality}}$

6. **The phase diagrams for the pure solvent (solid lines) and the solution (non-volatile solute, dashed line) are recorded below : The quantity indicated by L in the figure is :**



(A) Δp
(B) ΔT_f
(C) $K_b m$
(D) $K_f m$

Explanation

In the phase diagram:

- **Solid line** = Pure solvent's vapour pressure curve
- **Dashed line** = Solution's vapour pressure curve (lower due to non-volatile solute)
- At **1 atm**, the horizontal distance between the two curves represents the **elevation in boiling point**

The solution reaches 1 atm at a **higher temperature** than pure solvent.

Approach

At 1 atm pressure:

- Pure solvent boils at temperature T_b°
- Solution boils at temperature T_b (higher)
- L $= T_b - T_b^\circ = \Delta T_b =$ Elevation in boiling point

Since $\Delta T_b = K_b \times m$, the quantity L represents $K_b m$.

Answer

Option (C) $K_b m$
L represents the elevation in boiling point $= \Delta T_b = K_b m$

TYPE–2 : Calculate Molecular Weight of Solute

1. **Elevation in boiling point was 0.52 °C when 6 g of a compound x was dissolved in 100 g of water. Molecular weight of x is :(K = 5.2 K mol^{-1} 100 g H_2O)**
   (1) 120
   (2) 60
   (3) 100
   (4) 342

Explanation

Given:

- $\Delta T_b = 0.52°C$
- Mass of solute (w) = 6 g
- Mass of solvent (W) = 100 g
- $K_b = 5.2$ K mol^{-1} per 100 g H_2O

Note: K_b is given per 100 g, not per 1000 g (kg).

Approach

Since K_b is given per 100 g of water:

$$\Delta T_b = K_b \times \frac{w}{M}$$

$$0.52 = 5.2 \times \frac{6}{M}$$

$$M = \frac{5.2 \times 6}{0.52} = \frac{31.2}{0.52} = 60 \text{ g/mol}$$

Answer

Option (2) 60

2. **Boiling point of benzene is 353.23 K. When 1.8 g of non-volatile solute is dissolved in 90 g of benzene. Then boiling point raised to 354.11 K. Given K_b (benzene) = 2.53 K kg mol^{-1}. Then molecular mass of non volatile substance is :-**
   (1) 58 g mol^{-1}
   (2) 120 g mol^{-1}
   (3) 116 g mol^{-1}
   (4) 60 g mol^{-1}

Explanation

Given:

- $T_b^\circ = 353.23$ K, $T_b = 354.11$ K
- $\Delta T_b = 354.11 - 353.23 = 0.88$ K
- Mass of solute = 1.8 g
- Mass of benzene = 90 g = 0.09 kg
- $K_b = 2.53$ K kg mol^{-1}

Approach

Using the formula:

$$\Delta T_b = K_b \times \frac{w \times 1000}{M \times W}$$

$$0.88 = 2.53 \times \frac{1.8 \times 1000}{M \times 90}$$

$$M = \frac{2.53 \times 1.8 \times 1000}{0.88 \times 90}$$

$$M = \frac{4554}{79.2} = 57.5 \approx 58 \text{ g/mol}$$

Answer

Option (1) 58 g mol^{-1}

3. **If 0.15 g of a solute, dissolved in 15 g of solvent, is boiled at a temperature higher by 0.216°C, than that of the pure solvent. The molecular weight of the substance, (Molal elevation constant for the solvent is 2.16°C) is**
   (1) 10.1
   (2) 100
   (3) 1.01
   (4) 1000

Explanation

Given:

- $w = 0.15$ g (mass of solute)
- $W = 15$ g (mass of solvent)
- $\Delta T_b = 0.216°\text{C}$
- $K_b = 2.16°\text{C kg mol}^{-1}$

Approach

$$\Delta T_b = K_b \times \frac{w \times 1000}{M \times W}$$

$$0.216 = 2.16 \times \frac{0.15 \times 1000}{M \times 15}$$

$$0.216 = \frac{2.16 \times 150}{15M} = \frac{324}{15M} = \frac{21.6}{M}$$

$$M = \frac{21.6}{0.216} = 100 \text{ g/mol}$$

Quick check: Notice $\Delta T_b = 0.216$ and $K_b = 2.16$, ratio is exactly 0.1, which helps verify our answer.

Answer

Option (2) 100

4. **Elevation in boiling point was 0.52 °C when 6 g of a compound x was dissolved in 100 g of water. Molecular weight of x is : (K = 0.52 kg mol^{-1})**
   (A) 120
   (B) 60
   (C) 100
   (D) 342

Explanation

Given:

- $\Delta T_b = 0.52°\text{C}$
- $w = 6$ g, $W = 100$ g
- $K_b = 0.52$ K kg mol^{-1}

Approach

$$\Delta T_b = K_b \times \frac{w \times 1000}{M \times W}$$

$$0.52 = 0.52 \times \frac{6 \times 1000}{M \times 100}$$

$$1 = \frac{6000}{100M} = \frac{60}{M}$$

$$M = 60 \text{ g/mol}$$

Note: This is likely urea (NH_2CONH_2, M = 60)!

Answer

Option (B) 60

5. **A 2% solution of glucose has the same elevation in the boiling point as that of a 5% solution of a non-volatile solute. The molar mass of the solute is :** [NSEC-2003]
   (A) 180
   (B) 450
   (C) 72
   (D) 18

Explanation

Given:

- 2% glucose solution: 2 g glucose in 100 g solution (98 g water)
- 5% unknown solution: 5 g solute in 100 g solution (95 g water)
- ΔT_b is same for both
- $M_{\text{glucose}} = 180$ g/mol

Approach

Since ΔT_b is same and using same solvent (water):

$$\text{Molality}_{\text{glucose}} = \text{Molality}_{\text{solute}}$$

$$\frac{w_1/M_1}{W_1} = \frac{w_2/M_2}{W_2}$$

Assuming similar solvent masses (approximately):

$$\frac{2/180}{98} \approx \frac{5/M}{95}$$

$$\frac{2}{180} \approx \frac{5}{M}$$

$$M = \frac{5 \times 180}{2} = 450 \text{ g/mol}$$

Answer

Option (B) 450

TYPE–3 : Calculate Boiling Point of Solution

1. **At 100°C the vapour pressure of a solution of 6.5g of a solute in 100 g water is 732 mm. If $K_b = 0.52$ °C m^{-1}, the boiling point of this solution will be :-**

(1) 101°C
(2) 100°C
(3) 102°C
(4) 103°C

Explanation

Given:

- VP of solution at 100°C = 732 mm Hg
- VP of pure water at 100°C = 760 mm Hg
- $K_b = 0.52°\text{C/m}$

The solution boils when its VP = atmospheric pressure (760 mm Hg).

Approach

Step 1: Find mole fraction of solute using RLVP

$$\frac{P^\circ - P_s}{P^\circ} = \chi_{\text{solute}}$$

$$\frac{760 - 732}{760} = \frac{28}{760} = 0.0368$$

Step 2: For dilute solution, $\chi_{\text{solute}} \approx \frac{n_{\text{solute}}}{n_{\text{solvent}}}$

Step 3: Calculate molality

$$m = \frac{\chi_{\text{solute}} \times 1000}{M_{\text{water}}} = \frac{0.0368 \times 1000}{18} \approx 2.04 \text{ m}$$

Step 4: Calculate ΔT_b

$$\Delta T_b = K_b \times m = 0.52 \times 2.04 \approx 1.06°\text{C}$$

Step 5: Boiling point $= 100 + 1.06 \approx 102°\text{C}$

Answer

Option (3) 102°C

2. **The molal elevation constant for water is 0.56° K kg mol^{-1}. Calculate the boiling of the solution made by dissolving 6.0 gm of urea in 200 gm of water**

(1) 100.28° C
(2) 100° C
(3) 0.28° C
(4) 200.28° C

Explanation

Given:

- $K_b = 0.56$ K kg mol^{-1}
- Mass of urea $= 6.0$ g, $M_{\text{urea}} = 60$ g/mol
- Mass of water $= 200$ g

Approach

Step 1: Calculate ΔT_b

$$\Delta T_b = K_b \times \frac{w \times 1000}{M \times W}$$

$$\Delta T_b = 0.56 \times \frac{6 \times 1000}{60 \times 200}$$

$$\Delta T_b = 0.56 \times \frac{6000}{12000} = 0.56 \times 0.5 = 0.28°\text{C}$$

Step 2: Calculate boiling point

$$T_b = T_b^\circ + \Delta T_b = 100 + 0.28 = 100.28°\text{C}$$

Answer

Option (1) 100.28° C

3. **When 0.6 g of urea dissolved in 100 g of water, the water will boil at (K_b for water = 0.52 kJ. mol^{-1} and normal boiling point of water = 100°C) :** [NSEC-2001]

(A) 373.052 K

(B) 273.52 K

(C) 372.48 K

(D) 273.052 K

Explanation

Given:

- Mass of urea $= 0.6$ g, $M_{\text{urea}} = 60$ g/mol
- Mass of water $= 100$ g
- $K_b = 0.52$ K kg mol^{-1} (Note: it should be K kg mol^{-1}, not kJ)
- Normal BP of water $= 100°\text{C} = 373$ K

Approach

$$\Delta T_b = K_b \times \frac{w \times 1000}{M \times W}$$

$$\Delta T_b = 0.52 \times \frac{0.6 \times 1000}{60 \times 100}$$

$$\Delta T_b = 0.52 \times \frac{600}{6000} = 0.52 \times 0.1 = 0.052 \text{ K}$$

Boiling point $= 373 + 0.052 = 373.052$ K

Answer

Option (A) 373.052 K

4. **Water is added to the solution such that the mole fraction of water in the solution becomes 0.9. The boiling point of the solution is**
   (1) 354.7 K
   (2) 375.5 K
   (3) 376.2 K
   (4) 380.4 K

Explanation

Given:

- Mole fraction of water (χ_{water}) = 0.9
- Mole fraction of solute (χ_{solute}) = 1 - 0.9 = 0.1
- K_b for water = 0.52 K kg mol^{-1}

Approach

For dilute solutions:

$$\chi_{\text{solute}} \approx \frac{n_{\text{solute}}}{n_{\text{solvent}}} = \frac{m \times M_{\text{solvent}}}{1000}$$

$$0.1 = \frac{m \times 18}{1000}$$

$$m = \frac{0.1 \times 1000}{18} = 5.56 \text{ mol/kg}$$

$$\Delta T_b = K_b \times m = 0.52 \times 5.56 = 2.89 \text{ K}$$

But with $\chi = 0.1$ (not very dilute), use exact formula:

$$m = \frac{\chi_{\text{solute}} \times 1000}{(1 - \chi_{\text{solute}}) \times 18} = \frac{0.1 \times 1000}{0.9 \times 18} = 6.17$$

$\Delta T_b = 0.52 \times 6.17 = 3.2$ K
BP = 373 + 3.2 = 376.2 K

Answer

Option (3) 376.2 K

5. **An aqueous solution containing 1g of urea boils at 100.25°C. The aqueous solution containing 3 g of glucose in the same volume will boil at -**
   (A) 100.75 °C
   (B) 100.5 °C
   (C) 100°C
   (D) 100.25°C

Explanation

Given:

- 1 g urea $\rightarrow \Delta T_b = 0.25°\text{C}$
- $M_{\text{urea}} = 60$ g/mol, $M_{\text{glucose}} = 180$ g/mol
- 3 g glucose in same volume of water

Approach

$\Delta T_b \propto$ (number of moles of solute)
For urea: $n = \frac{1}{60}$ mol **For glucose:** $n = \frac{3}{180} = \frac{1}{60}$ mol
Since both have the **same number of moles** in the same mass of solvent:

$$\Delta T_b \text{ (glucose)} = \Delta T_b \text{ (urea)} = 0.25°\text{C}$$

Boiling point $= 100 + 0.25 = 100.25°\text{C}$
Key insight: 1 g urea and 3 g glucose have equal moles!

Answer

Option (D) 100.25°C
Both solutions have equal molality, so same ΔT_b.

TYPE–4 : Calculate K_b (Ebullioscopic Constant)

1. **If the elevation in boiling point of a solution of 10 g of solute (mol wt. = 100) in 100 g of water is ΔT_b, then the ebullioscopic constant of water is** [NCERT Pg. 50]
   (1) $100\Delta T_b$
   (2) ΔT_b
   (3) $\frac{\Delta T_b}{10}$
   (4) $10\Delta T_b$

Explanation

Given:

- Mass of solute $(w) = 10$ g
- Molar mass $(M) = 100$ g/mol
- Mass of water $(W) = 100$ g
- Elevation $= \Delta T_b$

Approach

Using: $\Delta T_b = K_b \times \frac{w \times 1000}{M \times W}$

$$\Delta T_b = K_b \times \frac{10 \times 1000}{100 \times 100}$$

$$\Delta T_b = K_b \times \frac{10000}{10000} = K_b \times 1$$

$$\boxed{K_b = \Delta T_b}$$

Note: The numbers are chosen such that molality = 1 mol/kg, making K_b numerically equal to ΔT_b.

Answer

Option (2) ΔT_b

2. **The rise in the boiling point of a solution containing 1.8g of glucose in 100 g of a solvent is 0.1°C. The molal elevation constant of the liquid is**
   (1) 0.01 K/m
   (2) 0.1 K/m
   (3) 1 K/m
   (4) 10 K/m

Explanation

Given:

- Mass of glucose $= 1.8$ g, $M_{\text{glucose}} = 180$ g/mol
- Mass of solvent $= 100$ g
- $\Delta T_b = 0.1°\text{C}$

Approach

Step 1: Calculate molality

$$m = \frac{w \times 1000}{M \times W} = \frac{1.8 \times 1000}{180 \times 100} = \frac{1800}{18000} = 0.1 \text{ mol/kg}$$

Step 2: Calculate K_b

$$K_b = \frac{\Delta T_b}{m} = \frac{0.1}{0.1} = 1 \text{ K/m}$$

Answer

Option (3) 1 K/m

TYPE–5 : Formula Derivation & Relation Based

1. **W gm of non-volatile organic substance of molecular mass M is dissolved in 250 gm benzene. Molal elevation constant of benzene is K_b. Elevation in its boiling point is given by**

   (1) $\frac{M}{K_b W}$

   (2) $\frac{4K_b W}{M}$

   (3) $\frac{K_b W}{4M}$

   (4) $\frac{K_b W}{M}$

Explanation

Given:

- Mass of solute = W g
- Molar mass = M g/mol
- Mass of benzene = 250 g
- Molal elevation constant = K_b

Approach

Using the formula:

$$\Delta T_b = K_b \times \frac{w \times 1000}{M \times W_{\text{solvent}}}$$

$$\Delta T_b = K_b \times \frac{W \times 1000}{M \times 250}$$

$$\Delta T_b = K_b \times \frac{1000W}{250M} = K_b \times \frac{4W}{M} = \frac{4K_b W}{M}$$

Answer

Option (2) $\dfrac{4K_bW}{M}$

2. **1 g of a non volatile non electrolyte solute is dissolved in 100 g of two different solvents A and B whose ebullioscopic constants are in the ratio of 1 : 5. The ratio of the elevation in their boiling points $\dfrac{\Delta T_b(A)}{\Delta T_b(B)}$ is :** [JEE(Main) 2019 Online (10-04-19)S2, 4/120]
   (1) 1 : 5
   (2) 10 : 1
   (3) 1 : 0.2
   (4) 5 : 1

Explanation

Given:

- Same mass of solute (1 g) in both solvents
- Same mass of solvent (100 g) in both cases
- $K_b(A) : K_b(B) = 1 : 5$

Approach

Since $\Delta T_b = K_b \times m$ and molality (m) is same in both cases (same mass of solute and solvent):

$$\frac{\Delta T_b(A)}{\Delta T_b(B)} = \frac{K_b(A) \times m}{K_b(B) \times m} = \frac{K_b(A)}{K_b(B)} = \frac{1}{5}$$

So $\Delta T_b(A) : \Delta T_b(B) = 1 : 5$

Note: Option (3) says 1 : 0.2 which is same as 1 : 1/5 = 5 : 1, so be careful!

Actually 1 : 5 is correct.

Answer

Option (1) 1 : 5

$\Delta T_b \propto K_b$ when molality is constant.

3. **If the elevation in boiling point of a solution of non-volatile, non-electrolytic and non-associating solute in solvent (K_b = x K. kg.mol^{-1}) is yK, then the depression in freezing point of solution of same concentration would be (K_f of the solvent = z K. kg. mol^{-1})**
   (1) $\dfrac{2xy}{y}$
   (2) $\dfrac{yz}{x}$
   (3) $\dfrac{xz}{y}$
   (4) $\dfrac{yz}{2x}$

Explanation

Given:

- $K_b = x$ K kg mol^{-1}
- $\Delta T_b = y$ K
- $K_f = z$ K kg mol^{-1}
- Same concentration (molality) for both

Approach

Step 1: Find molality from elevation data

$$\Delta T_b = K_b \times m$$

$$y = x \times m$$
$$m = \frac{y}{x}$$

Step 2: Calculate freezing point depression

$$\Delta T_f = K_f \times m = z \times \frac{y}{x} = \frac{yz}{x}$$

Answer

Option (2) $\frac{yz}{x}$

TYPE–6 : Mole Fraction & VP Based Numericals

1. **Elevation in b.p. of an aqueous urea solution is 0.52°. (K_b = 0.52° mol^{-1} kg) Hence, mole-fraction of urea in this solution is :**
   (1) 0.982
   (2) 0.567
   (3) 0.943
   (4) 0.018

Explanation

Given:

- $\Delta T_b = 0.52°$C
- $K_b = 0.52°$ mol^{-1} kg

Find: Mole fraction of urea (χ_{urea})

Approach

Step 1: Calculate molality

$$m = \frac{\Delta T_b}{K_b} = \frac{0.52}{0.52} = 1 \text{ mol/kg}$$

This means 1 mol urea in 1000 g water.

Step 2: Calculate moles of water

$$n_{\text{water}} = \frac{1000}{18} = 55.56 \text{ mol}$$

Step 3: Calculate mole fraction of urea

$$\chi_{\text{urea}} = \frac{n_{\text{urea}}}{n_{\text{urea}} + n_{\text{water}}} = \frac{1}{1 + 55.56} = \frac{1}{56.56} = 0.0177 \approx 0.018$$

Answer

Option (4) 0.018

2. **For a dilute solution containing 2.5 g of a non-volatile non-electrolyte solute in 100 g of water, the elevation in boiling point at 1 atm pressure is 2°C. Assuming concentration of solute is much lower than the concentration of solvent, the vapour pressure (mm of Hg) of the solution is (take K_b = 0.76 K kg mol^{-1})** [IIT 2012, 3/136]
   (A) 724
   (B) 740
   (C) 736
   (D) 718

Explanation

Given:

- Mass of solute = 2.5 g
- Mass of water = 100 g
- $\Delta T_b = 2°\text{C}$
- $K_b = 0.76$ K kg mol^{-1}

At 100°C, VP of pure water = 760 mm Hg

Approach

Step 1: Find molality

$$m = \frac{\Delta T_b}{K_b} = \frac{2}{0.76} = 2.63 \text{ mol/kg}$$

Step 2: Find moles of solute in 100 g water

$$n_{\text{solute}} = 2.63 \times 0.1 = 0.263 \text{ mol}$$

Step 3: Find moles of water

$$n_{\text{water}} = \frac{100}{18} = 5.56 \text{ mol}$$

Step 4: Find mole fraction of solute

$$\chi_{\text{solute}} = \frac{0.263}{0.263 + 5.56} = \frac{0.263}{5.823} = 0.0452$$

Step 5: Calculate VP using Raoult's Law

$$\frac{P^\circ - P_s}{P^\circ} = \chi_{\text{solute}}$$

$$P_s = P^\circ(1 - \chi_{\text{solute}}) = 760 \times (1 - 0.0452) = 760 \times 0.9548 = 725.6$$

Closest answer: 724 mm Hg

Answer

Option (A) 724

— END OF SOLUTIONS —

This is my year. I will not waste it!