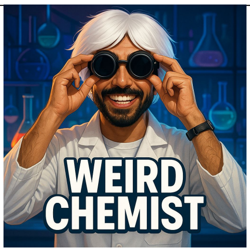

DPP–10 [Electrolyte (van't Hoff Factor)] – SOLUTIONS

Chapter: Solution

"Marks ke liye na daantne wale parents, dil se sabse zyada bharosa rakhte hain."

TYPE–1 : Conceptual – van't Hoff Factor, Dissociation & Association

Solution 1

Explanation

The van't Hoff factor (i) represents the ratio of actual number of particles in solution to the number of formula units dissolved.

- **Dissociation**: One molecule breaks into multiple particles $\rightarrow i > 1$
- **Association**: Multiple molecules combine into one particle $\rightarrow i < 1$
- **No change**: Non-electrolyte $\rightarrow i = 1$

Approach

Think of it like population changes in a city:
Dissociation (like families separating): $NaCl \rightarrow Na^+ + Cl^-$

- Start with 1 formula unit
- End with 2 particles
- $i = 2 > 1$

Association (like people forming groups): $2\ CH_3COOH \rightarrow (CH_3COOH)_2$

- Start with 2 molecules
- End with 1 dimer
- $i < 1$

The question asks which is correct about association: i is less than one!

Answer

(4) Less than one in case of association

Solution 2

Explanation

Glucose ($C_6H_{12}O_6$) is a non-electrolyte that doesn't dissociate or associate in aqueous solution. It remains as individual molecules.

Approach

Like sugar cubes in water: Each glucose molecule stays independent, doesn't break apart or join with others.
For non-electrolytes:

$$i = \frac{\text{actual particles}}{\text{formula units dissolved}} = \frac{1}{1} = 1.0$$

No dissociation, no association $\Rightarrow i = 1.0$

Answer

(2) 1.0

Solution 3

Explanation

A compound can show different behavior in different solvents:

- In one solvent: dissociates $\rightarrow i > 1$
- In another solvent: associates $\rightarrow i < 1$

Approach

Context matters: Like a person acting differently in different social situations!
Example: Benzoic acid

- In water: dissociates partially $\rightarrow i > 1$
- In benzene: dimerizes through H-bonding $\rightarrow i < 1$

Order matters in the answer: dissociation first, then association.

Answer

(3) Greater than one and less than one

Solution 4

Explanation

For a weak electrolyte A_xB_y that partially dissociates:

$$\mathrm{A}_x\mathrm{B}_y \rightleftharpoons x\mathrm{A}^{y+} + y\mathrm{B}^{x-}$$

The relationship between degree of dissociation (α) and van't Hoff factor (i) is derived from particle count.

Approach

Derivation - like counting before and after a party:
Initial: 1 mole of A_xB_y
After dissociation:

- Undissociated: $1 - \alpha$
- A^{y+} ions: $x\alpha$
- B^{x-} ions: $y\alpha$

Total particles:

$$i = (1 - \alpha) + x\alpha + y\alpha = 1 + (x + y - 1)\alpha$$

Rearranging:

$$i - 1 = (x + y - 1)\alpha$$

$$\alpha = \frac{i - 1}{x + y - 1}$$

Answer

(3) $\alpha = \frac{i-1}{(x+y-1)}$

Solution 5

Explanation

If substance A shows molecular mass corresponding to A_3, it means three molecules of A have associated to form A_3 trimer.

Approach

Association - like carpooling: Three people (molecules) in one car (trimer).

$$3\mathrm{A} \rightarrow \mathrm{A}_3$$

Calculation:

$$i = \frac{\text{actual particles}}{\text{expected particles}} = \frac{1}{3}$$

Three molecules became one particle!

Answer

(4) $\frac{1}{3}$

Solution 6

Explanation

For electrolytes, the experimental (observed) molar mass is calculated assuming no dissociation. Since electrolytes actually dissociate into more particles, the observed molar mass appears lower than the true molar mass.
The relationship: $M_{\text{observed}} = \frac{M_{\text{true}}}{i}$
Since $i > 1$ for electrolytes, $M_{\text{observed}} < M_{\text{true}}$

Approach

Why molar mass appears lower:
Imagine you calculated molar mass from osmotic pressure:

$$M = \frac{mRT}{\pi V}$$

But $\pi_{\text{actual}} = i \times \pi_{\text{expected}}$ (more particles!)
So: $M_{\text{observed}} = \frac{mRT}{i \times \pi_{\text{expected}} \times V} = \frac{M_{\text{true}}}{i}$
For electrolytes: $i > 1$, so observed M is less than calculated/true M.

Answer

(2) Greater than 1

Solution 7

Explanation

NaCl is a strong electrolyte that dissociates:

$$NaCl- > Na + +Cl-$$

So $i = 2$. The observed molar mass from osmotic pressure will be:

$$M_{\text{observed}} = \frac{M_{\text{true}}}{i} = \frac{58.5}{2} = 29.25$$

This is lower than the theoretical value (58.5).

Approach

Osmotic pressure method underestimates electrolyte molar mass:
NaCl dissociates into 2 ions, creating twice as many particles as expected.
This higher particle count produces higher osmotic pressure, which when used to calculate M, gives a lower value.
Result: Observed M ¡ Theoretical M

Answer

(2) Lower than the theoretical value

Solution 8

Explanation

Benzoic acid (C_6H_5COOH) in benzene forms dimers through hydrogen bonding:

$$2C_6H_5COOH \rightleftharpoons (C_6H_5COOH)_2$$

This association means $i < 1$, so the observed molecular weight is higher than the formula weight of a single molecule.

Approach

Dimerization through H-bonding:
In benzene (non-polar solvent), benzoic acid molecules pair up through hydrogen bonds between COOH groups.
Result: Fewer particles than expected → $i < 1$

$$M_{\text{observed}} = \frac{M_{\text{true}}}{i} > M_{\text{true}}$$

The observed M corresponds to roughly 2 × (formula weight) = dimer

Answer

(2) Dimerization of benzoic acid

TYPE–2 : Comparing Colligative Properties of Electrolytes

Solution 9

Explanation

KCl is an electrolyte that dissociates: KCl -¿ K+ + Cl-, so $i = 2$
Sugar (sucrose) is a non-electrolyte: $i = 1$
For equal molar concentrations, the ratio of colligative properties = ratio of i values.

Approach

Comparing the effects:
Colligative property ∝ number of particles ∝ i

$$\frac{\text{CP}_{\text{KCl}}}{\text{CP}_{\text{sugar}}} = \frac{i_{\text{KCl}}}{i_{\text{sugar}}} = \frac{2}{1} = 2$$

KCl produces twice the effect!

Answer

(3) 2

Solution 10

Explanation

Vapor pressure lowering is a colligative property that depends on the number of solute particles.
For 0.1 M solutions:

- $NaCl \rightarrow Na^+ + Cl^-$: $i = 2$, effective C = $0.1 \times 2 = 0.2$ M
- $CuSO_4 \rightarrow Cu^{2+} + SO_4^{2-}$: $i = 2$, effective C = 0.2 M
- $K_2SO_4 \rightarrow 2K^+ + SO_4^{2-}$: $i = 3$, effective C = 0.3 M

Approach

Count the particles:
VP lowering $\propto$ effective concentration
Ratio: $0.2 : 0.2 : 0.3$
Simplify: $2 : 2 : 3$ or $1 : 1 : 1.5$

Answer

(2) In the ratio of 1 : 1 : 1.5

Solution 11

Explanation

The substance that produces the most particles will decrease vapor pressure the most.
Count particles from 0.1 M solutions:

- KCl: 2 particles (0.2 M effective)
- Urea: 1 particle (0.1 M effective)
- $BaCl_2 \rightarrow Ba^{2+} + 2Cl^-$: 3 particles (0.3 M effective)
- NaCl: 2 particles (0.2 M effective)

Approach

Maximum particles = maximum effect:
$BaCl_2$ gives the most particles (3 per formula unit)
More particles → greater VP lowering → lowest VP

Answer

(3) 0.1 M $BaCl_2$

Solution 12

Explanation

Higher particle concentration → lower vapor pressure
For equimolar solutions:

- Glucose: $i = 1$ (1 particle)
- NaCl: $i = 2$ (2 particles)
- $Ba(NO_3)_2 \rightarrow Ba^{2+} + 2NO_3^-$: $i = 3$ (3 particles)

VP order: Highest i gives lowest VP

Approach

Ranking vapor pressures:
Most particles → lowest VP
$\mathrm{VP}_{\mathrm{Glucose}}$ ¿ $\mathrm{VP}_{\mathrm{NaCl}}$ ¿ $\mathrm{VP}_{\mathrm{Ba(NO_3)_2}}$
(1 particle) ¿ (2 particles) ¿ (3 particles)

Answer

(1) Glucose ¿ NaCl ¿ $\mathbf{Ba(NO_3)_2}$

Solution 13

Explanation

Lowest vapor pressure = highest particle concentration
Count particles from 0.1 M solutions:

- $BaCl_2$: 3 particles ($Ba^{2+} + 2Cl^-$)
- Urea: 1 particle
- Na_2SO_4: 3 particles ($2Na^+ + SO_4^{2-}$)
- Na_3PO_4: 4 particles ($3Na^+ + PO_4^{3-}$)

Approach

Maximum dissociation wins:
Na_3PO_4 produces 4 particles - the most!
Most particles → least vapor pressure

Answer

(4) 0.1 M $\mathbf{Na_3PO_4}$

Solution 14

Explanation

Boiling point elevation $\Delta T_b \propto i$
For same molar concentration:

- $AlCl_3 \rightarrow Al^{3+} + 3Cl^-$: $i = 4$
- $CaCl_2 \rightarrow Ca^{2+} + 2Cl^-$: $i = 3$

Since $i_{AlCl_3} > i_{CaCl_2}$, we have $T_1 > T_2$

Approach

More particles = higher boiling point:
$AlCl_3$ gives 4 particles per formula unit
$CaCl_2$ gives 3 particles per formula unit
Therefore: $T_1 > T_2$

Answer

(2) $T_1 > T_2$

Solution 15

Explanation

For 1% (w/v) solutions, we need to find which gives the most particles per gram.

$$\text{Particles} = \frac{\text{mass}}{M} \times i$$

Calculate for each:

- Glucose (M=180, i=1): $\frac{1}{180} \times 1 = 0.0056$ mol particles
- Sucrose (M=342, i=1): $\frac{1}{342} \times 1 = 0.0029$ mol particles
- NaCl (M=58.5, i=2): $\frac{1}{58.5} \times 2 = 0.034$ mol particles
- Urea (M=60, i=1): $\frac{1}{60} \times 1 = 0.017$ mol particles

Approach

NaCl wins: Low molar mass + dissociation into 2 ions
Most particles → highest boiling point

Answer

(3) 1% NaCl in water

Solution 16

Explanation

Boiling point elevation $\propto C \times i$
Calculate effective concentration for each:

- (i) 10^{-4} M NaCl: $10^{-4} \times 2 = 2 \times 10^{-4}$ M
- (ii) 10^{-4} M Urea: $10^{-4} \times 1 = 1 \times 10^{-4}$ M
- (iii) 10^{-3} M $MgCl_2$: $10^{-3} \times 3 = 3 \times 10^{-3}$ M
- (iv) 10^{-2} M NaCl: $10^{-2} \times 2 = 2 \times 10^{-2}$ M

Approach

Order effective concentrations:
1×10^{-4} ¡ 2×10^{-4} ¡ 3×10^{-3} ¡ 2×10^{-2}
(ii) ¡ (i) ¡ (iii) ¡ (iv)

Answer

(3) (ii) ¡ (i) ¡ (iii) ¡ (iv)

Solution 17

Explanation

Freezing point depression $\Delta T_f \propto i$
Higher i → more depression → lower freezing point
For 1 M solutions:

- Urea: $i = 1$ (lowest depression, **highest freezing point**)
- NaCl: $i = 2$
- Na_2SO_4: $i = 3$
- $Al_2(SO_4)_3$: $i = 5$ ($2Al^{3+} + 3SO_4^{2-}$) (most depression, lowest FP)

Approach

Least particles = highest freezing point:
Urea doesn't dissociate, so it has the least effect on FP.

Answer

(1) 1M urea

Solution 18

Explanation

Largest freezing point depression = most particles
For 0.10m solutions:

- KCl: $i = 2$ ($K^+ + Cl^-$)
- $C_6H_{12}O_6$: $i = 1$
- $Al_2(SO_4)_3$: $i = 5$ ($2Al^{3+} + 3SO_4^{2-}$)
- K_2SO_4: $i = 3$ ($2K^+ + SO_4^{2-}$)

Approach

$Al_2(SO_4)_3$ produces most ions:
5 particles per formula unit → largest depression

Answer

(3) $Al_2(SO_4)_3$

Solution 19

Explanation

Highest freezing point = least depression = fewest particles
For equimolal solutions:

- $C_6H_5NH_3Cl \rightarrow C_6H_5NH_3^+ + Cl^-$: $i = 2$
- $Ca(NO_3)_2 \rightarrow Ca^{2+} + 2NO_3^-$: $i = 3$
- $La(NO_3)_3 \rightarrow La^{3+} + 3NO_3^-$: $i = 4$
- $C_6H_{12}O_6$ (Glucose): $i = 1$ (non-electrolyte)

Approach

Glucose is the winner:
No dissociation → least particles → least depression → highest FP

Answer

(4) $C_6H_{12}O_6$ (Glucose)

Solution 20

Explanation

Minimum freezing point = maximum depression = most particles
Calculate effective concentration (C × i):

- 0.01 M NaCl: $0.01 \times 2 = 0.02$ M
- 0.005 M C_2H_5OH: $0.005 \times 1 = 0.005$ M
- 0.005 M MgI_2: $0.005 \times 3 = 0.015$ M
- 0.005 M $MgSO_4$: $0.005 \times 2 = 0.01$ M

Approach

NaCl has highest effective concentration:
0.02 M is the maximum → minimum freezing point

Answer

(1) **0.01 M NaCl**

Solution 21

Explanation

Lowest freezing point = most particles from 0.1 M solutions
Count ions:

- Potassium Sulphate (K_2SO_4): 3 ions
- Sodium Chloride (NaCl): 2 ions
- Urea: 1 particle (non-electrolyte)
- Glucose: 1 particle (non-electrolyte)

Approach

K_2SO_4 produces most ions:
3 particles → maximum depression → lowest FP

Answer

(1) **Potassium Sulphate**

Solution 22

Explanation

Maximum freezing point = minimum depression = fewest particles
For 1 molar solutions:

- NaCl: $i = 2$
- KCl: $i = 2$
- $CaCl_2$: $i = 3$
- Urea: $i = 1$ (non-electrolyte)

Approach

Urea produces fewest particles:
$i = 1 \rightarrow$ least depression $\rightarrow$ maximum freezing point

Answer

(4) 1 molar of urea solution

Solution 23

Explanation

$Ca(NO_3)_2$ is a strong electrolyte that dissociates:

$$\mathrm{Ca(NO_3)_2 \rightarrow Ca^{2+} + 2NO_3^-}$$

Since $i > 1$, the freezing point depression will be significant, pushing the freezing point below 0°C.

Approach

Any electrolyte solution freezes below 0°C:
Dissociation creates more particles → depression → FP ¡ 0°C

Answer

(4) Below 0°C

Solution 24

Explanation

Higher particle concentration → more depression → lower freezing point
Calculate effective concentrations:

- 0.2M $BaCl_2$: $0.2 \times 3 = 0.6$ M
- 0.2M KCl: $0.2 \times 2 = 0.4$ M
- 0.1M Na_2SO_4: $0.1 \times 3 = 0.3$ M

Order of effective C: $0.3 < 0.4 < 0.6$
Order of FP (inverse): highest to lowest

Approach

Least depression first:
Na_2SO_4 (0.3) ¿ KCl (0.4) ¿ $BaCl_2$ (0.6)

Answer

(3) 0.1M Na_2SO_4, 0.2M KCl, 0.2M $BaCl_2$

Solution 25

Explanation

Osmotic pressure $\pi = iCRT$
For equal concentration (0.1 M):

- NaCl: $i = 2$, so $\pi_1 = 2 \times 0.1 \times RT$
- Na_2SO_4: $i = 3$, so $\pi_2 = 3 \times 0.1 \times RT$

Therefore: $\pi_2 > \pi_1$

Approach

Na_2SO_4 produces more ions:
3 ions vs 2 ions → higher osmotic pressure

Answer

(2) The osmotic pressure Na_2SO_4 is more than NaCl solution

Solution 26

Explanation

Highest osmotic pressure = most particles
For 0.1 M solutions:

- (1) $Al_2(SO_4)_3$: $i = 5$, effective = 0.5 M
- (2) $BaCl_2$: $i = 3$, effective = 0.3 M
- (3) Na_2SO_4: $i = 3$, effective = 0.3 M
- (4) Mix of (2) and (3): When equal volumes mixed, concentrations halve but we get both:
  - $BaCl_2$: $0.05\text{M} \times 3 = 0.15\text{M}$
  - Na_2SO_4: $0.05\text{M} \times 3 = 0.15\text{M}$
  - Total = 0.3M

Approach

$Al_2(SO_4)_3$ wins:
5 ions per formula unit → 0.5 M effective → highest π

Answer

(1) 0.1M $Al_2(SO_4)_3$

Solution 27

Explanation

Minimum osmotic pressure = fewest particles
For equal concentrations:

- $BaCl_2$: $i = 3$
- $AgNO_3$: $i = 2$
- Na_2SO_4: $i = 3$
- $(NH_4)_3PO_4$: $i = 4$

Approach

$AgNO_3$ produces fewest ions:
Only 2 ions → minimum osmotic pressure

Answer

(2) $AgNO_3$

Solution 28

Explanation

For equimolar solutions, osmotic pressure $\propto i$

- Glucose: $i = 1$
- NaCl: $i = 2$
- $BaCl_2$: $i = 3$

Order: $BaCl_2$ ¿ NaCl ¿ Glucose

Approach

More ions = higher pressure:
3 ions ¿ 2 ions ¿ 1 molecule

Answer

(2) $BaCl_2$ ¿ NaCl ¿ Glucose

Solution 29

Explanation

Isotonic solutions have equal osmotic pressures, which requires equal effective concentrations ($C \times i$).
Check each option:

- (1) 0.1M urea (i=1): 0.1M effective; 0.1M NaCl (i=2): 0.2M effective - NOT isotonic
- (2) 0.1M urea (i=1): 0.1M effective; 0.2M $MgCl_2$ (i=3): 0.6M effective - NOT isotonic
- (3) 0.1M NaCl (i=2): 0.2M effective; 0.1M Na_2SO_4 (i=3): 0.3M effective - NOT isotonic
- (4) 0.1M $Ca(NO_3)_2$ (i=3): 0.3M effective; 0.1M Na_2SO_4 (i=3): 0.3M effective - ISOTONIC!

Approach

Match effective concentrations:
Both $Ca(NO_3)_2$ and Na_2SO_4 give 3 ions, so equal molar solutions are isotonic.

Answer

(4) 0.1M $Ca(NO_3)_2$ and 0.1M Na_2SO_4

Solution 30

Explanation

- KNO_3 is a strong electrolyte: $i \approx 2$
- CH_3COOH is a weak electrolyte: $i \approx 1$ (very weak ionization)

For 0.1M solutions: $P_1 > P_2$

Approach

Strong vs weak electrolyte:
KNO_3 fully dissociates → more particles → $P_1 > P_2$

Answer

(3) $P_1 > P_2$

Solution 31

Explanation

Maximum osmotic pressure = most particles
For 1M solutions:

- $AgNO_3$: $i = 2$
- Na_2SO_4: $i = 3$
- $(NH_4)_3PO_4$: $i = 4$ ($3NH_4^+ + PO_4^{3-}$)
- $MgCl_2$: $i = 3$

Approach

$(NH_4)_3PO_4$ produces most ions:
4 ions → maximum osmotic pressure

Answer

(3) $(NH_4)_3PO_4$

Solution 32

Explanation

Alum is $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$, or more precisely $KAl(SO_4)_2 \cdot 12H_2O$
It dissociates: $KAl(SO_4)_2 \rightarrow K^+ + Al^{3+} + 2SO_4^{2-}$
So $i = 4$
For 1M solutions:

- Glucose: $i = 1$
- Urea: $i = 1$
- Alum: $i = 4$
- NaCl: $i = 2$

Approach

Alum produces most ions:
4 particles per formula unit → highest osmotic pressure

Answer

(3) 1M Alum solution

Solution 33

Explanation

Calculate effective concentration $(C \times i)$ for each:

- 0.500 M C_2H_5OH: $0.500 \times 1 = 0.500$ M
- 0.100 M $Mg_3(PO_4)_2 \rightarrow 3Mg^{2+} + 2PO_4^{3-}$: $0.100 \times 5 = 0.500$ M
- 0.250 M KBr: $0.250 \times 2 = 0.500$ M
- 0.125 M $Na_3PO_4 \rightarrow 3Na^+ + PO_4^{3-}$: $0.125 \times 4 = 0.500$ M

Approach

All equal!
Each solution has effective concentration of 0.500 M → same osmotic pressure

Answer

(3) They all have the same osmotic pressure

Solution 34

Explanation

For 0.1M solutions:

- Urea: $i = 1$ (non-electrolyte)
- Na_3PO_4: $i = 4$
- $Al_2(SO_4)_3$: $i = 5$

Effects on colligative properties:

- Higher $i \rightarrow$ lower vapor pressure
- Higher $i \rightarrow$ lower freezing point (higher depression)
- Higher $i \rightarrow$ higher boiling point (higher elevation)

Approach

Analyze each statement:
(a) Urea has lowest VP and FP? NO - it has highest VP and FP (least particles)
(b) Urea has highest VP and FP? YES - fewest particles
(c) $Al_2(SO_4)_3$ has highest BP elevation? YES - most particles
(d) $Al_2(SO_4)_3$ has highest FP depression? YES - most particles
So b, c, and d are correct!

Answer

(3) b, c and d

TYPE–3 : Numerical – ΔT_f, ΔT_b, π with van't Hoff Factor

Solution 35

Explanation

NaCl dissociates: NaCl -¿ Na+ + Cl-, so $i = 2$
Given:

- 0.5 mol NaCl in 500 g = 0.5 kg water
- Molality = $\frac{0.5}{0.5} = 1$ molal
- $K_f = 1.8$ K kg mol^{-1}
- $K_b = 0.5$ K kg mol^{-1}

Approach

Calculate both effects:
Freezing point:

$$\Delta T_f = i \times K_f \times m = 2 \times 1.8 \times 1 = 3.6\text{C}$$

$$T_f = 0 - 3.6 = -3.6\text{C}$$

Boiling point:

$$\Delta T_b = i \times K_b \times m = 2 \times 0.5 \times 1 = 1\text{C}$$

$$T_b = 100 + 1 = 101\text{C}$$

Answer

(2) -3.6**C, 101°C**

Solution 36

Explanation

For NaCl solution: $i = 2$, molality $= 0.1$ molal, $K_b = 0.51$

Approach

BP elevation calculation:

$$\Delta T_b = i \times K_b \times m = 2 \times 0.51 \times 0.1 = 0.102\text{C}$$

$$T_b = 100 + 0.102 \approx 100.1\text{C}$$

Answer

(2) 100.1°C

Solution 37

Explanation

KCl dissociates completely: KCl -¿ K+ + Cl-, so $i = 2$
For 1.0 molal solution with $K_b = 0.52$:

Approach

Calculate elevation:

$$\Delta T_b = i \times K_b \times m = 2 \times 0.52 \times 1 = 1.04\text{C}$$

$$T_b = 100 + 1.04 = 101.04\text{C}$$

Answer

(2) 101.04°C

Solution 38

Explanation

For 1 molal NaCl with 100% dissociation: $i = 2$, $K_f = 1.86$

Approach

FP depression:

$$\Delta T_f = i \times K_f \times m = 2 \times 1.86 \times 1 = 3.72\text{C}$$

$$T_f = 0 - 3.72 = -3.72\text{C}$$

Answer

(2) -3.72**C**

Solution 39

Explanation

0.585% NaCl means 0.585 g per 100 mL = 5.85 g per liter
For NaCl (M = 58.5): $i = 2$

Approach

Calculate osmotic pressure:
Step 1: Molarity

$$C = \frac{5.85}{58.5} = 0.1 \text{ M}$$

Step 2: Osmotic pressure

$$\pi = iCRT = 2 \times 0.1 \times 0.0821 \times 300 = 4.926 \approx 5 \text{ atm}$$

Answer

(2) 5 atm

Solution 40

Explanation

Weak acid HX is 20% ionized:

$$HX \rightleftharpoons H^+ + X^-$$

For weak electrolyte: $i = 1 + \alpha$ (since it produces 2 particles when ionized)
$i = 1 + 0.2 = 1.2$

Approach

Calculate BP elevation:

$$\Delta T_b = i \times K_b \times m = 1.2 \times 0.52 \times 0.2 = 0.1248 \approx 0.125\text{C}$$

Answer

(2) 0.125

Solution 41

Explanation

Same weak acid HX with 20% ionization: $i = 1 + \alpha = 1.2$
For 0.5 molal solution:

Approach

FP lowering:

$$\Delta T_f = i \times K_f \times m = 1.2 \times 1.86 \times 0.5 = 1.116 \approx 1.12 \text{ K}$$

Sign: This is lowering, so -1.12 K

Answer

(2) -1.12 **K**

Solution 42

Explanation

HBr is a strong acid that's 90% ionized:

$$HBr \rightarrow H^+ + Br^-$$

$i = 1 + \alpha = 1 + 0.9 = 1.9$
Mass of HBr = 8.1 g, M = 81 g/mol

Approach

Calculate depression:
Step 1: Molality

$$m = \frac{8.1/81}{0.1} = \frac{0.1}{0.1} = 1 \text{ molal}$$

Step 2: Depression

$$\Delta T_f = i \times K_f \times m = 1.9 \times 1.86 \times 1 = 3.534 \approx 3.53\text{C}$$

$$T_f = 0 - 3.53 = -3.53\text{C}$$

Answer

(2) -3.53**C**

Solution 43

Explanation

K_2SO_4 dissociates: K2SO4 -¿ 2K+ + SO4^{2-}
With 90% dissociation ($\alpha = 0.9$):

$$i = 1 + (n-1)\alpha = 1 + (3-1) \times 0.9 = 1 + 1.8 = 2.8$$

Where $n = 3$ (total ions when fully dissociated)

Approach

Calculate osmotic pressure:

$$\pi = iCRT = 2.8 \times 0.1 \times 0.0821 \times 300 = 6.896 \approx 6.89 \text{ atm}$$

Answer

(1) 6.89 atm

Solution 44

Explanation

Isotonic means equal osmotic pressures.
For Na_2SO_4 (complete dissociation): $i = 3$
Effective concentration $= 0.02 \times 3 = 0.06$ M
For sucrose (non-electrolyte): $i = 1$
Required concentration $= 0.06$ M

Approach

Match effective concentrations:

$$\pi_{\mathrm{Na_2SO_4}} = \pi_{\text{sucrose}}$$
$$3 \times 0.02 \times RT = C_{\text{sucrose}} \times RT$$
$$C_{\text{sucrose}} = 0.06 \text{ M}$$

Answer

(3) 0.06 M

Solution 45

Explanation

For non-electrolyte B (0.1 M): $\pi = 2P$
So: $0.1 \times RT = 2P$, which means $RT = 20P$
For ternary electrolyte A: $i = 3$ (produces 3 ions)
For 0.05 M solution of A:

$$\pi_A = i \times C \times RT = 3 \times 0.05 \times 20P = 3P$$

Approach

Ternary means 3 ions:
Half the concentration but triple the particles → $\pi = 3P$

Answer

(4) 3 P

Solution 46

Explanation

Compare osmotic pressures:
CH_3COOH: Weak acid, very weak ionization, $i \approx 1.01$

$$C_1 = \frac{6}{60} = 0.1 \text{ M}$$
$$\pi_1 \approx 1.01 \times 0.1 \times RT$$

KCl: Strong electrolyte, $i = 2$

$$C_2 = \frac{7.45}{74.5} = 0.1 \text{ M}$$
$$\pi_2 = 2 \times 0.1 \times RT$$

Approach

Strong electrolyte wins:
$\pi_2 \approx 2 \times 0.1 \times RT$ is much greater than $\pi_1 \approx 1 \times 0.1 \times RT$
Therefore: $\pi_1 < \pi_2$

Answer

(2) $\pi_1 < \pi_2$

Solution 47

Explanation

5.8% (wt/vol) NaCl = 58 g/L
Molarity: $\frac{58}{58.5} \approx 1$ M
With $i = 2$: effective concentration = 2 M
This is isotonic with 2 M sucrose (non-electrolyte)

Approach

Match effective concentrations:
NaCl: 1 M × 2 = 2 M effective
Sucrose (non-electrolyte): Need 2 M actual concentration

Answer

(3) 2 M sucrose solution

TYPE–4 : Calculating van't Hoff Factor (i)

Solution 48

Explanation

Barium hydroxide is $Ba(OH)_2$, which dissociates:

$$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$$

Total ions = 3
Therefore: $i = 3$

Approach

Count the ions:
$Ba(OH)_2 \rightarrow 1\ Ba^{2+} + 2\ OH^- = 3$ particles
$i = 3$

Answer

(2) 3

Solution 49

Explanation

$K_3[Fe(CN)_6]$ dissociates:

$$K_3[Fe(CN)_6] \rightarrow 3K^+ + [Fe(CN)_6]^{3-}$$

Total ions = 4
Therefore: $i = 4$

Approach

Complex ion stays together:
3 K^+ ions + 1 complex ion $[Fe(CN)_6]^{3-}$ = 4 particles

Answer

(2) 4

Solution 50

Explanation

Hg_2Cl_2 dissociates:

$$Hg_2Cl_2 \rightarrow Hg_2^{2+} + 2Cl^-$$

Total ions = 3, so $i = 3$
Check which has same i:

- NaCl: $i = 2$
- Na_2SO_4: $i = 3$ YES!
- $Al(NO_3)_3$: $i = 4$
- $Al_2(SO_4)_3$: $i = 5$

Approach

Match the particle count:
$Na_2SO_4 \rightarrow 2Na^+ + SO_4^{2-} = 3$ particles
Same as Hg_2Cl_2!

Answer

(2) Na_2SO_4

Solution 51

Explanation

$Al_2(SO_4)_3$ dissociates:

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

Total ions = 5, so $i = 5$
Check options:

- $K_3[Fe(CN)_6]$: $i = 4$ ($3K^+$ + 1 complex)
- $Al(NO_3)_3$: $i = 4$ ($1Al^{3+} + 3NO_3^-$)
- $K_4[Fe(CN)_6]$: $i = 5$ ($4K^+$ + 1 complex) YES!
- K_2SO_4: $i = 3$

Approach

K_4[Fe(CN)$_6$] gives 5 particles:
4 K^+ ions + 1 complex ion = 5 particles, matching $Al_2(SO_4)_3$

Answer

(3) K_4[Fe(CN)$_6$]

Solution 52

Explanation

Use the formula: $\Delta T_f = i \times K_f \times m$
Given:

- Mass of Na_2SO_4 = 5 g, M = 142 g/mol
- Mass of water = 45 g = 0.045 kg
- $\Delta T_f = 3.82$C
- $K_f = 1.86$C m^{-1}

Approach

Calculate i:
Step 1: Molality

$$m = \frac{5/142}{0.045} = \frac{0.0352}{0.045} = 0.782 \text{ molal}$$

Step 2: Calculate i

$$i = \frac{\Delta T_f}{K_f \times m} = \frac{3.82}{1.86 \times 0.782} = \frac{3.82}{1.455} = 2.63$$

Answer

(2) 2.63

Solution 53

Explanation

The complex $[Co(NH_3)_5(NO_2)]Cl$ dissociates:

$$[Co(NH_3)_5(NO_2)]Cl \rightarrow [Co(NH_3)_5(NO_2)]^+ + Cl^-$$

Use $\Delta T_f = i \times K_f \times m$ to find i:

$$i = \frac{\Delta T_f}{K_f \times m} = \frac{0.00732}{1.86 \times 0.0020} = \frac{0.00732}{0.00372} \approx 2$$

Approach

Van't Hoff factor $= 2$:
This means 1 complex cation + 1 Cl^- = 2 ions

Answer

(2) 2

Solution 54

Explanation

$Ba(NO_3)_2$ dissociates:

$$Ba(NO_3)_2 \rightarrow Ba^{2+} + 2NO_3^-$$

For complete dissociation: $i = 3$
For partial dissociation: $i = 1 + (n-1)\alpha$
Given $i = 2.74$, find α:

Approach

Calculate degree of dissociation:

$$i = 1 + (n-1)\alpha$$

$$2.74 = 1 + (3-1)\alpha$$

$$1.74 = 2\alpha$$

$$\alpha = 0.87 = 87\%$$

Answer

(2) 87%

Solution 55

Explanation

Hg_2Cl_2 dissociates:

$$Hg_2Cl_2 \rightarrow Hg_2^{2+} + 2Cl^-$$

With 80% ionization ($\alpha = 0.8$), $n = 3$:

$$i = 1 + (n-1)\alpha = 1 + (3-1) \times 0.8 = 1 + 1.6 = 2.6$$

Approach

Partial dissociation:
Not all Hg_2Cl_2 ionizes, so i is between 1 and 3.
$i = 2.6$

Answer

(2) 2.6

Solution 56

Explanation

Phenol associates (dimerizes):

$$2C_6H_5OH \rightleftharpoons (C_6H_5OH)_2$$

For association with degree 40% ($\alpha = 0.4$):
Using: $i = 1 - \frac{\alpha}{n}$ where $n = 2$ for dimerization

$$i = 1 - \frac{0.4}{2} = 1 - 0.2 = 0.8$$

Approach

Association decreases particle count:
Start with 2 molecules, 40% form dimers
$i = 0.8$ (less than 1)

Answer

(2) 0.8

Solution 57

Explanation

Isotonic solutions: $\pi_1 = \pi_2$
For NaCl: $\pi_1 = i \times C_1 \times RT$

$$C_1 = \frac{1.17}{58.5} = 0.02 \text{ M}$$

For glucose: $\pi_2 = 1 \times C_2 \times RT$

$$C_2 = \frac{7.2}{180} = 0.04 \text{ M}$$

Since isotonic:

$$i \times 0.02 = 1 \times 0.04$$

$$i = 2$$

Approach

Using isotonicity to find i:
Glucose effective C = 0.04 M
NaCl must have same effective C: $i \times 0.02 = 0.04$
$i = 2$

Answer

(2) 2

Solution 58

Explanation

Isotonic: $\pi_1 = \pi_2$
Na_2SO_4 dissociates: Na2SO4 -¿ 2Na+ + SO4^{2-}
For partial dissociation: $i = 1 + (n-1)\alpha$ where $n = 3$

$$i \times 0.004 \times RT = 1 \times 0.010 \times RT$$

$$i = \frac{0.010}{0.004} = 2.5$$

Now find α:

$$2.5 = 1 + (3-1)\alpha$$

$$1.5 = 2\alpha$$

$$\alpha = 0.75 = 75\%$$

Approach

Two-step calculation:
First find i from isotonicity, then calculate α

Answer

(3) 75%

Solution 59

Explanation

Depression ratio = i ratio

$$\frac{\Delta T_{f,A}}{\Delta T_{f,B}} = \frac{i_A}{i_B} = \frac{2}{1}$$

Given A remains normal: $i_A = 1$
Therefore: $i_B = 0.5$
Since $i_B < 1$, substance B must be associated.

Approach

$i < 1$ means association:
Molecules combine → fewer particles → $i < 1$

Answer

(2) Associated

Solution 60

Explanation

$K_4[Fe(CN)_6]$ dissociates:

$$K_4[Fe(CN)_6] \rightarrow 4K^+ + [Fe(CN)_6]^{4-}$$

With partial dissociation (α):

$$i = 1 + (5-1)\alpha = 1 + 4\alpha$$

Abnormal molar mass:

$$M_{\text{observed}} = \frac{M_{\text{normal}}}{i} = \frac{M_{\text{normal}}}{1+4\alpha} = M_{\text{normal}}(1+4\alpha)^{-1}$$

Approach

Relationship between M and i:
Higher i → lower observed M
$M_{\text{observed}} = \frac{M_{\text{normal}}}{i}$

Answer

(4) $M_{\textbf{normal}}(1+4\alpha)^{-1}$

Solution 61

Explanation

AB_2 dissociates: AB2 -¿ $A^{2+} + 2B-$
Complete dissociation gives 3 ions, so $n = 3$

$$i = \frac{M_{\text{normal}}}{M_{\text{observed}}} = \frac{164}{65.6} = 2.5$$

Using: $i = 1 + (n-1)\alpha$

$$2.5 = 1 + (3-1)\alpha$$

$$1.5 = 2\alpha$$

$$\alpha = 0.75 = 75\%$$

Approach

From observed M to α:
Lower observed M → higher i → higher dissociation

Answer

(3) 75%

Solution 62

Explanation

Calcium nitrate is $Ca(NO_3)_2$:

$$Ca(NO_3)_2 \rightarrow Ca^{2+} + 2NO_3^-$$

Complete dissociation gives 3 ions, $n = 3$

$$i = \frac{164}{65.6} = 2.5$$

$$\alpha = \frac{i-1}{n-1} = \frac{2.5-1}{3-1} = \frac{1.5}{2} = 0.75 = 75\%$$

Approach

Same as previous question:
$Ca(NO_3)_2$ is also AB_2 type with $n = 3$

Answer

(3) 75%

TYPE–5 : Miscellaneous – When HgI_2 is added / Special Cases

Solution 63

Explanation

When HgI_2 is added to KI solution, a reaction occurs:

$$HgI_2 + 2KI \rightarrow K_2[HgI_4]$$

Analysis of particles:

- Before: $2KI \rightarrow 2K^+ + 2I^- = 4$ ions
- After: $K_2[HgI_4] \rightarrow 2K^+ + [HgI_4]^{2-} = 3$ ions

Number of particles decreases: $4 \rightarrow 3$
Therefore, colligative properties decrease. Freezing point depression decreases, meaning freezing point is raised!

Approach

Complex formation reduces particle count:
Before adding HgI_2: - 2 KI in solution = 4 ions ($2K^+ + 2I^-$)
After adding HgI_2: - Forms $K_2[HgI_4]$ = 3 ions ($2K^+$ + 1 complex ion)
Fewer particles → less depression → freezing point rises!

Answer

(2) Freezing point is raised

Excellent work mastering van't Hoff factor!

– *Weird Chemist*