Class :- IX

Depression In Freezing Point (Cryoscopy)

Teaching Task

Q1) Ans :- A

Solution :- Mass of 8.2L water = 8.2 kg or 8200g

because density is 1.

Mass of density alcohol added = Density × volume

= 0.8 × 2000

= 1600 g.

$\Delta T_f = K_f m.$

$= 1.86 \times \frac{1600}{32} \times \frac{1}{8200} \times 1000$

$= 11.34.$

The lowest temperature = $-11.34°C$

Q2) Ans :- A.

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

	$K_3[Fe(CN)_6]$	$3K^+$	$Fe(CN)_6^{3-}$
Before dissociation	1	0	0
After dissociation	0	3	1

Total no. of particles = 4.

Vant' Hoff factor, $i = 4$.

$\Delta T_f = \frac{1000 \times K_f \times w}{m \times W} \times i$

$= \frac{1000 \times 1.86 \times 0.1 \times 4}{329 \times 100}$

$= 2.3 \times 10^{-2}\ °C.$

$\Delta T_f' = 0 - 2.3 \times 10^{-2} \longrightarrow T_f' = -2.3 \times 10^{-2}\ °C$

Q3). Ans:- D.

Solution:- The molal freezing point depression constant is the depression in freezing point for 1 molal solution.

$\Delta T_f = K_f \times m$

when $m = 1$, $\Delta T_f = K_f$.

When ΔT_f is the depression in freezing point of the solvent in a solution of a non-volatile solute of molality m, then quantity.

$\lim_{m \to 0} (\Delta T_f / m) =$ Molal depression constant $= K_f$

Q4) Ans:- A

Solution:- $\Delta T_f = K_f \cdot m$.

Freezing point of surcose is 271 K.

$\Delta T_f = 273.15\,K - 271\,K = 2.15\,K$.

5% solution means 5 grams of solute in 100 grams of solution. So 5grams solute, 95 grams water.

Moles of Surcose $= \frac{5}{342} = 0.0146$ mol.

Molality of surcose solution $= \frac{0.0146\,mol}{0.095\,kg} = 0.1537$ mol/kg

Moles of glucose $= \frac{5}{180} = 0.0278$ mol.

Molality of glucose solution $= \frac{0.0278}{0.095\,kg} = 0.2926$ mol/kg

$\frac{\Delta T_f\,(glucose)}{\Delta T_f\,(surcose)} = \frac{0.2926}{0.1537} = 1.903 \rightarrow \Delta T_f(glucose) = 1.903 \times 2.15\,K = 4.09\,K.$

Freezing point $= 273.15\,K - 4.09\,K = 269.07\,K$.

Q5) Ans:- B.

Solution:- Given Component 1 = Benzene.

Component 2 = Solute.

$w_1 = 50g$, $\Delta T_f = 0.40K$, $K_f = 5.12$ K Kg mol^{-1}

$w_2 = 1.00g$

Molar mass of solute $M_2 = ?$

$\Delta T_f = K_f . m$

m = molality → $m = \frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg.}}$

no. of moles of solute $= \frac{\text{Actual mass}}{\text{Molar mass.}} = \frac{w_2}{M_2}$

$$m = \frac{w_2}{M_2} \times \frac{1}{w_1}.$$

$w_1 = 50g$ → $w_1 = 0.05$ kg.

$$\Delta T_f = K_f . \frac{w_2}{M_2} \times \frac{1}{w_1}$$

$$M_2 = \frac{K_f . w_2}{\Delta T_f . w_1}.$$

$$= \frac{5.12 \times 1}{0.40 \times 0.05}$$

$= 256$ g/mol.

Q6) Ans:- D.

Solution:- $\Delta T_f = i \cdot K_f \cdot \frac{m}{M}$.

For substance A, $\Delta T_{f_A} = 0.10°C$.

mass of solute = 400g.

mass of solvent = 100g.

M_A = molar mass of A.

For substance B, $\Delta T_{f_B} = 0.20°C$

mass of solute = 4g.

mass of solvent = 100g.

M_B = molar mass of B

K_f & solvent mass are constant, So

$$\frac{\Delta T_{f_A}}{\Delta T_{f_B}} = \frac{\frac{m_A}{M_A}}{\frac{m_B}{M_B}} \Rightarrow \frac{0.1}{0.2} = \frac{\frac{400}{M_A}}{\frac{4}{M_B}}$$

$$\frac{1}{2} = \frac{\cancel{400}\ 100}{M_A} \times \frac{M_B}{\cancel{4}}$$

$M_A = 200\ M_B$.

Q7) Ans:- B.

Solution:- Given, $\Delta T_f = 0.372°C$, $K_f = 1.8$ kg. K mol^{-1}.

Molar mass of urea = 60 g.

Given mass of water = 1 kg = 1000 gms.

$$\Delta T_f = K_f \times \frac{w_1}{M_1} \times \frac{1000}{w_2}$$

$$0.372 = 1.85 \times \frac{w_1}{60} \times \frac{\cancel{1000}\ 1}{\cancel{1000}}$$

$$w_1 = \frac{0.372 \times 60}{1.85} = 12.06$$

Q8) Ans:- A

Solution:- Given $x+y=0.1$.

$KCl \rightarrow x$ moles, $BaCl_2 \rightarrow y$ moles

$KCl \rightarrow K^+ + Cl^-$ $BaCl_2 \rightarrow Ba^{2+} + 2Cl^-$

$i=2$. $i=3$

Solvent $= 1$ kg.

$\Delta T_f = i K_f m$

$K_f = 1.85$ K/molal.

$\Delta T_f = (2x+3y)1.85$

$x+y=0.1$, let $x=0.01$, $y=0.09$.

$\Delta T_f = (2\times0.01 + 3\times0.09)\times1.85$

$= 0.5365$.

or $x=0.09$

$y=0.01$.

$\Delta T_f = (2\times0.09 + 3\times0.01)\times1.85$

$= 0.3885$

ΔT_f varies b/w 0.37 to 0.55

Q9) Ans:- A.

Solution:- $\Delta T_f = -0.30^\circ C$, V.P of pure water $(P^\circ) = 23.5$ mmHg.

Temperature $= 298$ K., $K_f = 1.86$ kg mol^{-1}

V.P of solution $(P) = ?$

$\Delta T_f = K_f \cdot m_2 \rightarrow m_2 = \frac{0.3}{1.86} = 0.1613.$

$\frac{n_2}{n_1} = \frac{0.1613\times18}{1000} = 2.9\times10^{-3} \rightarrow \frac{n_1}{n_1+n_2} = X_1 = \frac{1}{1+2.9\times10^{-3}}$

$= 0.997.$

$P = P^\circ X_1 = 23.51\times0.997 = 23.44$ mm.

Q10) Ans:- A.

Solution:- we have $\Delta T_f = K_f \times m$.

Given $\Delta T_f = 3.554$.

$K_f = 1.86$.

$$m = \frac{\Delta T_f}{K_f} = \frac{3.554}{1.86} = 1.91.$$

$$\text{Molarity} = \frac{\text{mass of solute}}{\text{molar mass of solute} \times \text{mass of solvent}}$$

$$1.911 = \frac{x}{342 \times 1.}$$

$$x = 342 \times 1.911 \doteq 653.562$$

Mass of solute $= 653.562$

Mass of ice separated $= 1000 - 653.84 = 353$ gms.

Q11) Ans:- A, D.

Solution:-

→ The vapour pressure of the solution is less than that of pure solvent.

→ Only solvent molecules solidify at the freezing point

Q12) Ans:- A.

Solution:- $K_f = \frac{\Delta T_f}{m}$.

$$\text{molality} = \frac{\frac{0.849}{M}}{0.050}.$$

$$1.24 \neq 34.3 \left[\frac{\frac{0.849}{M}}{0.050}\right]$$

$M = 469.68$.

The mercurous chloride is present in the form of Hg_2Cl_2

Q13) Ans:- A.

Solution:-

→ Depression of freezing point is a colligative property.

→ $\Delta T_f = K_f . m$.

$\Delta T_f \propto m$.

Q14) Ans:- D.

Solution:- mole of napthalene (n_2) = 0.1.

Mole of benzene (n_1) = 0.9.

Vapour pressure of benzene (P^o) = 760 mm.

B.P of benzene = 353 K.

V.P of solution = 670 mm

Freezing point of benzene = 278.5 K.

$\Delta H_{fus} = 10.67\ KJ\ mol^{-1}$.

$$\frac{P^o - P_s}{P_s} = \frac{W_2 \times Mw_1}{Mw_2 \times w_1}.$$

$$\frac{760-670}{670} = \frac{0.1 \times 78}{w_1}$$

$w_1 = 58.06\ g$.

weight of benzene = $0.9 \times 78 = 70.2g$.

Amount of benzene frozen out = $70.2 - 58.06$

$= 12.14\ g$.

Q15) Ans:- C

Solution:- $\frac{\Delta P}{P^o} = \frac{760-670}{670} = 0.13$

Q16) Ans:- C.

Solution:- $\Delta T_f = K_f m$.

$K_f = \Delta T_f$ when the molality is equal to 1.

Molality of glucose $= \frac{9}{180 \times 50} \times 1000$

$= 1.$

Q17) Ans:- D.

Solution:- $2NaI + HgI_2 \rightarrow Na_2HgI_4$.

As HgI_2 is added, the no. of molecules will decrease due to the formation of Na_2HgI_4. Therefore, pressure will increase. As more HgI_2 is added, pressure will remain constant (and NaI is consumed) after that as HgI_2 is sparingly soluble.

Integer Type

Q18) Ans:- 5

Solution:- Mass of acetic acid, $w_1 = 75\,g$.

Molar mass of ascorbic acid $(C_6H_8O_6) = 6 \times 12 + 8 \times 1 + 6 \times 16$
$= 176\,g\,mol^{-1}$

$\Delta T_f = 1.5\,K$.

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

$= \frac{1.5 \times 176 \times 75}{3.9 \times 1000}$

$w_2 = 5.08\,g$.

Q19) Ans:- 3.

Solution:- $\Delta T = K_f \times \frac{W_B \times 1000}{M_B \times W_A}$.

Given $\Delta T_f = 0.186°C$, $K_f = 1.86$, $W_A = 500cc$.

$$0.186 = 1.86 \times \frac{W_B \times 1000}{60 \times 500}$$

$$W_B = \frac{0.186 \times 30}{1.86} = 3g.$$

Matrix Matching

Q20) Ans:- D

Solution:-

1) Molar freezing constant → r) $\frac{RT_b^2 M}{1000 \Delta H_f}$

2) Molecular depression constant → s) $\frac{RT_b^2}{100 L_f}$

3) molal depression constant → p) $\frac{RT_b^2}{1000 L_f}$

4) Depression in freezing point → q) $K_f m$

Learner's Task

Q1) **Ans:-** A.

Solution:- Addition of glycol lowers the freezing point of water in the radiators, so that the cold winter temperatures wouldn't burst the lines and thus glycol-water mixture is used as antifreeze in radiators of cars.

Q2) **Ans:-** C.

Solution:- The freezing point depression is directly proportional to the no. of particles.

→ Glucose & urea do not dissociate, i → 1

→ NaCl (Na^+ and Cl^-) → i → 2.

→ $ZnSO_4$ (Zn^{2+} and SO_4^{2-}) → i → 2.

NaCl, $ZnSO_4$ has 2 ion, but $ZnSO_4$ has more charge increases the freezing point depression.

Q3) **Ans:-**

Solution:- Greater the no. of particles, lower freezing point lower no. of particles higher freezing point.

→ NaCl → i = 2

→ Sugar → i = 1.

→ $BaCl_2$ → i = 3

→ $FeCl_3$ → i = 4

∴ Sugar has lower particles. So it has higher freezing point.

Q4) Ans:- a.

Solution:- Aqueous solution of any substance if it is non volatile freezes below 0°c because the vapour pressure of the solution becomes lower than that of pure solvent.

Q5) Ans:- b.

Solution:- $K_f = 1.86$, $m = 0.1$.

$$\Delta T_f = K_f m$$
$$= 1.86 \times 0.1 = 0.186.$$

Q6) Ans:- a.

Solution:- Hg I reacts with KI, to form $K_2[HgI_4]$.
Due to this, the no. of ions decreases thus decreasing the van't Hoff factor.

$$\Delta T_f = i \times K_f \times m.$$

Since 'i' has decreased, it result in less depression in the freezing point causing the freezing point to rise.

Q7) Ans:- B

Solution:- $\Delta T_f \propto m$, $\Delta T_f \propto K_f \rightarrow \Delta T_f = K_f m$.

K_f is constant.

ΔT_f depends on molality. Molal depression constant does not depend on the nature of the solute. It is depends the nature of solvent.

Q8). Ans:- D.

Solution:- $m = \frac{K_f \times 1000 \times w}{W \times \Delta T_f}$ $\Delta T_f = 5.5 - 4.48 = 1.02$

$= \frac{5.1 \times 1000 \times 4.8}{60 \times 1.02}$

$= \frac{24480}{61.2} = 400$

Q9) Ans:- A.

Solution:- During the depression of freezing point in a solution, liquid solvent & solid solvent are in equilibrium. During freezing of a solution, only the solvent freezes out and the equilibrium exits b/w solid and liquid form of solvent.

Q10) Ans:- B.

Solution:- Freezing point is inversly proportional to mass percentage of the non-volatile electrolyte (Glucose)

1% > 2% > 3% > 10%.

JEE Main level Questions

Q1) **Ans:-** D

Solution:- $\Delta T_f = K_f \times \frac{w_1}{M_1} \times \frac{1000}{w_2}$.

Given, $w_1 = 2.56\,g$, $w_2 = 100g$, $\Delta T_f = 0.68^\circ C$.

$$0.68 = 6.8 \times \frac{2.56}{M} \times \frac{1000}{100}$$

$$0.68M = 68 \times 2.56$$

$$M = \frac{68 \times 2.56}{0.68} = 256.$$

Molecular mass of sulphur = 256.

Formula of Sulphur = S_8

Q2) **Ans:-** a.

Solution:- Non-volatile solute molecular mass same with any solvent.

Q3) **Ans:-** d.

Solution:- When a non-volatile, non-electrolyte is dissolved in a pure solvent the vapour pressure of the solvent is lowered, so addition of non-volatile solute decreases the freezing point of solution and addition of salt lowers the freezing point of water and thus snow melts.

Q4) Ans:- C

Solution:- $\Delta T_f = i K_f m_{solute}$

$\Delta T_{f_{urea}} : \Delta T_{f_{glucose}} : \Delta T_{f_{NaCl}} = i_{urea} : i_{glucose} : i_{NaCl}$.

i_{urea} & $i_{glucose} = 1$, $i_{NaCl} = 2$

$\Delta T_{f_u} : \Delta T_{f_g} : \Delta T_{f_{NaCl}} = 1:1:2$

Q5) Ans:- A

Solution:- $M_{AB_2} = \frac{1000 \times w_2 \times K_f}{\Delta T_f \times w_1}$.

$= \frac{1000 \times 1 \times 5.1}{2.3 \times 20} = 110.87 \text{ g/mol}$.

$M_{AB_4} = \frac{1000 \times 1 \times 5.1}{1.3 \times 20} = 196.15 \text{ g/mol}$.

Molar mass of AB_2 & AB_4 are 110.87, 196.15 respectively

$AB_2 = 110.87 \rightarrow x + 2y = 110.87 \rightarrow (1)$.

$AB_4 = 196.15 \rightarrow x + 4y = 196.15 \rightarrow (2)$

Subtract (2) - (1)

$x + 4y = 196.15$

$x + 2y = 110.87$

$2y = 85.28$.

$y = \frac{85.28}{2} = 42.64$.

substitute y in (1)

$x + 2(42.64) = 110.87$.

$x = 110.87 - 2 \times 42.64$

$= 25.59$.

$A = x = 25.594$.

$B = y = 42.644$.

Q6). Ans:- D.

Solution:- $\Delta T_f = K_f \times \frac{w_1}{M_1} \times \frac{1000}{w_2}$

Given $\frac{\Delta T_f}{K_f} = \frac{1}{1000}$, $w_1 = ?$, $w_2 = 1$ litre $= 1000$ ml.

Molar mass of water $= 18 \rightarrow$ for 1000 gms $\rightarrow$ 180 gms.

$$\frac{\Delta T_f}{K_f} = \frac{w_1}{M_1} \times \frac{1000}{w_2}$$

$$\frac{1}{1000} = \frac{w_1}{180} \times \frac{1000}{1000}$$

$$w_1 = \frac{180}{1000} = 0.18g.$$

Q7) Ans:- A

Solution:- Ideal solution containing non-volatile solute

$$\Delta T_f = K_f m$$

where $K_f = \frac{M_1 R T_f^*}{\Delta_{vap} H_m}$

Q8) Ans:- C.

Solution:- $\Delta T_b = K_b \cdot m$,

$\Delta T_f = K_f m$ $\Delta T_b + \Delta T_f = m(K_b + K_f)$ $T_b - T_b^\circ + T_f^\circ - T_f$.

$$= \frac{w_s}{M} \times \frac{1000}{w_0} (K_b + K_f) T_b - T_f + T_f^\circ - T_b^\circ$$

$$= \frac{x}{342} \times \frac{1000}{500} 2 \{(0.52) + 1.86\} 105$$

$$5 = \frac{2x}{342} (2.38) \Rightarrow x = \frac{342 \times 5}{2 \times 2.38} = 359.$$

Q9) Ans:- C.

Solution:- $\Delta T_f = K_f \times \frac{w_1}{M_1} \times \frac{1000}{w_2}$

Given $K_f = 1.86$, $w_1 = 100$, $M = 342$

at $\Delta T_f = 0.5$.

$0.5 = 1.86 \times \frac{100}{342} \times \frac{1000}{w_2}$

$w_2 = \frac{1.86}{0.5} \times \frac{100 \times 1000}{342}$

$= 1087.71.$

at $\Delta T_f = 0.38$.

$0.38 = \frac{1.86 \times x \times 1000}{342 \times 1087.7}$

$x = 77.49.$

∴ Given solution = 100 gms.

The ice freezes out $= 100 - 77.49 = 22.51 \approx 23.$

Q10) Ans:- A.

Solution:- Effective molarity = Given molarity × No. of particles per molecule in solution.

→ Higher the effective molarity, more is depression in freezing point.

0.05M KNO_3 > 0.04 M $CaCl_2$ > 0.14M Sugar > 0.075 $CuSO_4$.

↓

0.1 M < 0.12 M < 0.14 M < 0.15 M.

⇒ Effective molarity order

Advanced Level Questions

Q11) **Ans:-** A, C, D.

Solution:- For $Hg(NO_3)_2$

$$\Delta T_f = i K_f m.$$

$$0.0558 = i(1.86)\left(\frac{3.24/324}{1}\right)$$

$$i = 3.$$

i.e, $Hg(NO_3)_2 \rightarrow Hg^{2+} + 2NO_3^-$

$$i = 3.$$

So $Hg(NO_3)_2$ is completely ionized (100%)

For $HgCl_2$

$$\Delta T_f = i.\ K_f m.$$

$$0.0744 = i(1.86)\left(\frac{21.68/271}{2}\right)$$

$$i = \frac{0.0744 \times 2 \times 271}{1.86 \times 21.68} = 1$$

$$HgCl_2 \rightarrow Hg^{2+} + 2Cl^- \rightarrow i = 3.$$

i.e, $HgCl_2$ is unionized.

Q12) **Ans:-** A, B, C, D.

Solution:- According to Raoult's law, the addition of non volatile solid solute always lowers the V.P of pure solvent.

→ The solution will be in equilibrium with the solid phase at lower pressures hence at lower temperature.

→ The freezing point of a solvent in the solution containing non-volatile solid solute is always lower the F.P.

Q13) Ans:- C

Solution:- $P \propto \frac{1}{T}$.

On increasing the pressure, the freezing temperature decreases. It is true that the freezing point of water decreases as the pressure decreases. This is because water expands when it freezes, so compressing ice will tend to convert it to more compact liquid water. Thus, increasing the pressure lowers the freezing point.

→ The density of water is maximum at 4°C.

Q14) Ans:- D.

Solution:- The molality of benzene,

$$\frac{X_B}{X_A} = \frac{\frac{n_B}{n_A+n_B}}{\frac{n_A}{n_A+n_B}} \Rightarrow \frac{X_B}{X_A} = \frac{n_B}{n_A}$$

$$\frac{n_B}{n_A} = \frac{n_B}{W_A} \times \frac{M_A \times 1000}{1000} \Rightarrow m = \frac{n_B \times 1000}{W_A}.$$

$$\frac{X_A}{X_B} = m \times \frac{M_A}{1000}.$$

Molar mass of $C_6H_6 = (6 \times 12) + 6 = 78$.

Given $X_B = 0.2$, $X_A = 0.8$. $\Rightarrow \frac{0.2}{0.8} = m \times \frac{78}{1000}$

Molality, $m = 3.2$.

$\Delta T_f = K_f \times m$ {K_f of benzene 5.5}

$= 5.5 \times 3.2$

$= 17.6 \approx 17$

Q15) Ans:- D.

Solution:- The freezing point of a liquid is that temperature at which the liquid and its solid state exist in equilibrium with each other. It may be defined as the temperature at which the liquid & solid states of a substance have the same vapour pressure.

When a non-volatile, non-electrolyte is dissolved in a pure solvent the vapour pressure of the solvent is lowered, so addition of non-volatile solutes decreases the freezing point of solution.

Q16) Ans:- B.

Solution:-

$$K_F = \frac{R T_f^2 M}{1000\, \Delta H_{fus}}$$

For larger value of T_f and smaller value of enthalpy of the solid, the value of K_f would be larger.

Hence, a liquid having high freezing point and small enthalpy of freezing will be most suitable for determing the molecular mass of a compound by cryoscopic measurements.

Integer Type

Q17) **Ans:-** 2.

Solution:- Depression in freezing point $\Delta T_f = i \times K_f \times m$.

$$i = \frac{\Delta T_f}{K_f \times m}.$$

Given $\Delta T_f = 0 - (-0.00732) = 0.00732$

$m = 0.0020M$.

$K_f = 1.86°C/m$.

$$i = \frac{0.00732}{1.86 \times 0.0020} = 1.86 \approx 2$$

So, the compound $[Co(NH_3)_5(NO_2)]Cl$ in solution will dissociate into Cl^- and $[Co(NH_3)_5(NO_2)]^+$.

$n = 2$.

∴ 2 moles moles of ions are formed.

Q18) **Ans:-** 6.

Solution:- Given:- $\Delta T_f = 0.5$, $K_f = 1.86$, $M.W_{urea} = 60$.

Depression will be caused by water which exist as liquid at $-0.5°C$.

$W = 500 - 128 = 372g$.

$$\Delta T_f = K_f \times molality = \frac{1000 \times K_f \times w}{m \times W}.$$

$$0.5 = \frac{1000 \times 1.86 \times w}{60 \times 372}$$

$$w = \frac{0.5 \times 60 \times 372}{1000 \times 1.86}$$

$$\boxed{w = 6g}$$

Q19) Ans:- 3.

Solution:- Depression in freezing point $\Delta T_f = i \times K_f \times m$.

For, NaCl, $i = 2$ $\{NaCl \rightarrow Na^+ + Cl^-\}$.

K_f for water $= 1.86\ ^\circ C/m$.

$\Delta T_f = 2^\circ C$.

$\Delta T_f = i \times K_f \times m$.

$2 = 2 \times 1.86 \times m$

$m = 0.538$ moles/kg.

Equimolar means,

Molality of NaCl = Molality of $MgCl_2$.

For $MgCl_2$, $i = 3$ $\{MgCl_2 \rightarrow Mg^{+2} + 2Cl^-\}$.

$\Delta T_f = i \times K_f \times m$.

$= 3 \times 1.86 \times 0.538 = 3.002$

So, freezing point of $MgCl_2$ solution will be "$-3.002^\circ C$"

Matrix Matching

Q20) Ans:- A) P-2, Q-4, R-2, S-3.

Solution:-

P) Molal cryoscopic constant for water → 2) 1.86° kg/mol.

Q) The factor $\Delta T_f / K_f$ represents → 4) $\Delta T_f \propto m \rightarrow \Delta T_f = K_f m$. molality, $m = \frac{\Delta T_f}{K_f}$

R). K_f for water is → 2) 1.86° kg/mol.

S) Depression in freezing point → 3) $K_f \propto$ osmotic pressure.