Class 12 Chapter 1: Solutions Lecture 08

Vant Hoff Factor

⇒ 4 Colligative Properties

1. $\frac{P_A^o - P_A}{P_A^o} = X_{solute}$ Relative lowering in Vapour Pressure
2. $\Delta T_b = K_b \times m$ Elevation in Boiling Point
3. $\Delta T_f = K_f \times m$ Depression in Freezing Point
4. $\pi = MRT$ Osmotic Pressure.

⇒ Solute we used were all non-electrolytes like Urea, Glucose, Cane sugar, etc.

⇒ These solutes neither Dissociate or Associate in Solution.

Case of Electrolytes ÷ Solutes that Dissociates

$$NaCl_{(aq)} \longrightarrow Na^+_{(aq)} + Cl^{\ominus}_{(aq)}$$

no. of particles in solution Increases due to Dissociation

⇒ Colligative Properties will also Increase

(as Collig Prop depend upon no. of solute particles → see above formulae)

(Observed Collig prop will be diff from Calculated Collig Prop)

Van't Hoff Factor. (i)

$$(i) = \frac{\text{Total no of particles after Dissociation/Association}}{\text{Total no of particles before Dissociation/Association}}$$

Dissociation

$$NaCl \xrightarrow[\text{dissociat.}]{100\%} Na^+ + Cl^-$$

$\alpha = 1$

$i = \frac{2}{1}$ $i > 1$

$$MgCl_2 \xrightarrow[\text{dissociation}]{100\%} Mg^{2+} + 2Cl^{\ominus}$$

$\alpha = 1$

$i = \frac{3}{1}$ $i > 1$

$$Al_2(SO_4)_3 \xrightarrow[\text{Dissociation}]{100\%} 2Al^{3+} + 3SO_4^{2-}$$

$\alpha = 1$

$i = \frac{5}{1}$ $i > 1$

$$K_4[Fe(CN)_6] \xrightarrow[\text{dissociation}]{100\%} 4K^+ + [Fe(CN)_6]^{-4}$$

$\alpha = 1$

$i = \frac{5}{1}$ $i > 1$

Here, we assumed 100% dissociation, which is not always true,

$\Rightarrow$

If Degree of Dissociation is α

$$NaCl \longrightarrow Na^{+} + Cl^{\ominus}$$

initial $1 \qquad 0 \qquad 0$

equilibrium $1-\alpha \qquad \alpha \qquad \alpha$

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

$\boxed{i>1}$

$$MgCl_2 \longrightarrow Mg^{2+} + 2Cl^{-}$$

initial $1 \qquad 0 \qquad 0$

equilibrium $1-\alpha \qquad \alpha \qquad 2\alpha$

$$i = \frac{2\alpha+\alpha+1-\alpha}{1} = 1+2\alpha$$

General Case:

$\boxed{i>1}$

$$A_n \longrightarrow nA$$

$1 \qquad 0$

$1-\alpha \qquad n\alpha$

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

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

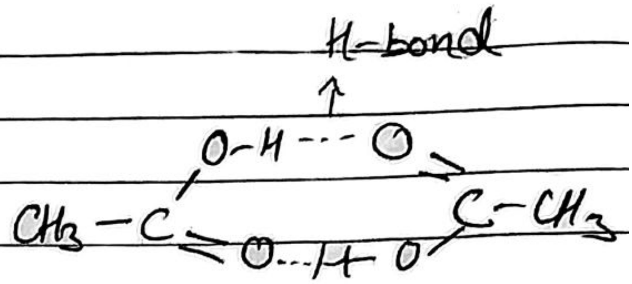
$$\boxed{\alpha = \frac{i-1}{n-1}}$$ Don't Learn Understand the Method.

In case of Dissociation

$\Rightarrow i>1$ Observed C.P. > Calculated C.P. (Normal)

Observed C.P. < Calculated C.P.
(Normal)

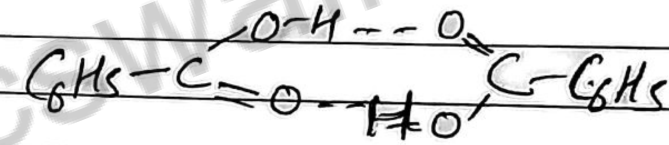
Association:

$2CH_3COOH \rightleftharpoons$ 

100% dimerisation association — Dimer

$i = \frac{1}{2}$ $\quad i < 1$

no. of particles decreases
⇒ Colligative properties will decrease

$2C_6H_5COOH \rightleftharpoons$ 

100% association — dimer

$i = \frac{1}{2}$ $\quad i < 1$

Carboxylic Acids in benzene → forms dimer

Trimer

$3A \longrightarrow A_3$

$i = \frac{1}{3}$ $\quad i < 1$

Tetramer

$4A \longrightarrow A_4$

$i = \frac{1}{4}$

Here we assumed 100% association, which is not always true

If degree of association is α

$$2CH_3COOH \rightleftharpoons (CH_3COOH)_2$$

	$2CH_3COOH$	$(CH_3COOH)_2$
initial	1	0
equilibrium	$1-\alpha$	$\frac{\alpha}{2}$

$$i = \frac{1-\alpha+\frac{\alpha}{2}}{1} = 1-\frac{\alpha}{2}$$

$$\boxed{i<1}$$

General case:

$$nA \longrightarrow A_n$$

	nA	A_n
initial	1	0
equilibrium	$1-\alpha$	$\frac{\alpha}{n}$

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

$$i = 1+\alpha\left(\frac{1}{n}-1\right)$$

$$\boxed{\frac{i-1}{\frac{1}{n}-1} = \alpha}$$ Don't Learn Understand the Method.

In Association, no of particles decreases

$\Rightarrow \boxed{i<1}$

Observed Colligative Property $\propto$ no of particles after dissociation / Association

Calculated Colligative Property $\propto$ no. of particles before dissociation / Association

$$\frac{\text{Observed C.P.}}{\text{Calculated C.P.}} = i = \frac{\text{no. of particles after ---}}{\text{no. of particles before -}}$$

So, Observed C.P. = $i \times$ Calculated C.P.

$$\frac{P_A^o - P_A}{P_A^o} = i \times X_{solute}$$

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

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

$$\pi = i \times M \times R \times T$$

Q1) Assuming 100% dissociation, state which will have highest Osmotic Pressure at same Temperature
1M $NaCl$
1M Na_2SO_4
1M $Al_2(SO_4)_3$

Solution: $\pi = MRT \times i$

$\pi \propto i$

$NaCl$ $i = 2$
Na_2SO_4 $i = 3$
$Al_2(SO_4)_3$ $i = 5$

Q2) A 2 molal solution of NaCl in water causes an elevation in boiling point of water by 1.88 K. find i and α.
(Kb for water is 0.52 K kg/mol)

Solution:

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

$$1.88 = 0.52 \times 2 \times i$$

$$i = \frac{1.88}{1.04} = \frac{94}{52} = \frac{47}{26}$$

$$\boxed{i = 1.8}$$

$$NaCl \longrightarrow Na^+ + Cl^-$$

1	0	0
$1-\alpha$	α	α

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

$$1.8 = 1+\alpha$$

$$\alpha = 0.8$$

$\Rightarrow$ 80% dissociation.

Q3) $\frac{M}{10}$ Solution of Potassium Ferrocyanide is 50% dissociated at 27°C. Calculate osmotic pressure.

Solution: $\pi = MRT \times i$

$= \frac{1}{10} \times 0.0821 \times 300 \times i$

$= \frac{1}{10} \times 0.0821 \times 300 \times 3$

$= 7.39$ atm

Calculation

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

$$\begin{array}{ccc} 1 & 0 & 0 \\ 1-\alpha & 4\alpha & \alpha \end{array}$$

$$i = \frac{1-\alpha+4\alpha+\alpha}{1} = 1+4\alpha$$

$\alpha = \frac{50}{100} = 0.5$

$i = 1+4\times 0.5 = 3$

Q5) A certain substance 'A' tetramerises in water to the extent of 80%. A solution of 2.5g of A in water (100g) lowers the freezing point by 0.3°C. The molar mass of A is (K_f = 1.86 K kg/mol)

Solution:

$$4A \longrightarrow A_4$$

$$1 \qquad 0$$

$$1-\alpha \qquad \frac{\alpha}{4}$$

$$i = \frac{1-\alpha+\frac{\alpha}{4}}{1}$$

$$i = 1-\frac{3\alpha}{4} \qquad \alpha = 0.8 \ (80\%)$$

$$i = 1-\frac{3\times0.8}{4}$$

$$\boxed{i = 0.4}$$

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

$$0.3 = 1.86 \times \frac{\frac{2.5}{x}}{\frac{100}{1000}} \times 0.4$$

$$\boxed{x = 62} \ g/mol$$

Abnormal Molar Mass of Solute

Dissociation

$$\underset{58.5}{NaCl} \longrightarrow \underset{29.25}{Na^+} + \underset{29.25}{Cl^-} \qquad \boxed{i > 1}$$

Normal Molar Mass should be 58.5 of (NaCl) solute molecuels

But

Observed Molar Mass of solute particles is (Na^+ & $Cl^{\ominus}$) 29.25 (Abnormal Molar Mass)

Here, no of particles increases

Obs Colligative prop increases

Obs ~~But~~ Molar Mass decreases

Association:

$$\underset{60}{2CH_3COOH} \rightleftharpoons \underset{120}{(CH_3COOH)_2} \qquad \boxed{i < 1}$$

Normal Molar Mass of solute is 60

But

Observed Molar Mass of Solute (dimers) is 120 (Abnormal Molar Mass)

Here, no of particles decreases

Obs. Collig prop decreases

Obs ~~But~~ Molar Mass Increases

⇓

$$\text{no of particles} \propto \text{Obs C.P.} \propto \frac{1}{\text{Obs Molar Mass}}$$

$$i = \frac{\text{Total no. of moles of solute After Diss / Assoc.}}{\text{Total no. of moles of solute Before Diss / Assoc}}$$

$$i = \frac{\text{Observed C.P.}}{\text{Normal (Calculated) C.P.}}$$

$$i = \frac{\text{Calculated (Normal) Molar Mass}}{\text{Observed (Abnormal) Molar Mass}}$$

example:

$$\underset{60}{2CH_3COOH} \longrightarrow \underset{120}{(CH_3COOH)_2}$$