van't Hoff Factor (i)

Question

Calculate ΔT_f when m moles of NaCl are added in 1 kg water.

Ans. Calculate d value (Normal Value)

$m_1 M_{normal} = w$

$NaCl \rightarrow Na^+ + Cl^-$
$m \quad m$

Actual value (Abnormal value)

$w = (2m) M_{abnormal}$

molality $= \frac{m}{1} = m$

$\Delta T_f = m k_f$

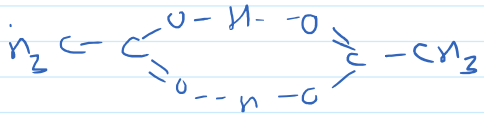
molality $= 2m$

$\Delta T_f = 2m k_f$

$i = \frac{\text{Abnormal colligative property}}{\text{Normal colligative property}}$ $\quad \frac{2m k_f}{m k_f} = 2$

$= \frac{\text{Number of particles after dissociation/association}}{\text{Number of particles before dissociation/association}}$ $\quad \frac{2m}{m} = 2$

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



$i = \frac{\text{normal molar mass}}{\text{abnormal molar mass}}$ $\quad \frac{w}{m(w)} = 2$

Formula when dissociation/association is not complete

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

$i = 1 + (n-1)\alpha$, α – Degree of dissociation
n → number of particles in which 1 particle of solute dissociate

eg: 1) $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

$t = 0$	C			
$t = \infty$	$C(1-\alpha)$	$C\alpha$	$C\alpha$	Total $C(1+\alpha)$

$i = \frac{C(1+\alpha)}{C} = 1+\alpha \qquad 1+(2-1)\alpha$

ii) $H_3PO_4 \rightleftharpoons 3H^+ + PO_4^{3-}$

$t=0$	C			
$t=\infty$	$C(1-\alpha)$	$3C\alpha$	$C\alpha$	Total $C(1+3\alpha)$

$i = \frac{C(1+3\alpha)}{C} = 1+3\alpha = 1+(4-1)\alpha$

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

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

$n \rightarrow$ number of particles which associate to form one particle

$\beta \rightarrow$ degree of association

eg

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

$t=0$	C		
$t=\infty$	$C(1-\beta)$	$\frac{C\beta}{2}$	Total $C-\frac{C\beta}{2} = C\left(1-\frac{\beta}{2}\right)$
	$C-C\beta$		

$i = \frac{C(1-\beta/2)}{C} = 1-\frac{\beta}{2} = 1+\left(\frac{1}{2}-1\right)\beta$

ii) $3A \rightleftharpoons A_3$

$t=0$	C		
$t=\infty$	$C(1-\beta)$	$\frac{C\beta}{3}$	Total $C-C\beta+\frac{C\beta}{3} = C-\frac{2}{3}\beta C$

$i = \frac{C\left(1-\frac{2}{3}\beta\right)}{C} = 1-\frac{2}{3}\beta = 1+\left(\frac{1}{3}-1\right)\beta$

New formulas

$\Delta T_f = imk_f \qquad \Delta T_b = imk_b \qquad \pi = iCRT \qquad RLVP = ix_B$