Change of State Previous Year Problems

15 December 2022 [redacted]

By how much the freezing point of benzene 5.53°C, be reduced if 10g hexane added to 100 g benzene?

(ΔHf for benzene = 9.836 kJ mol^{-1}).

formula

$$\Delta T_f = K' x_B \quad ; \quad \left(K' = \frac{RT^{*2}}{\Delta H_f} \right)$$

Given: $T^* = 5.53^\circ C + 273\,K = 278.53\,K$

$R = 8.314\ J\,K^{-1} mol^{-1}$

$\Delta H_f = 9.836\ kJ\,mol^{-1} = 9.836 \times 10^3\ J\,mol^{-1}$

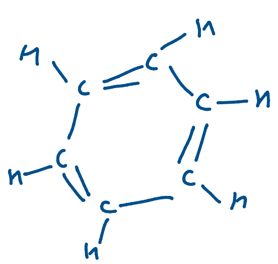
A = Solvent = Benzene (↑ large quantity)

B = Solute = Hexane. (↑ less quantity.)

no. of moles of $A = \dfrac{\text{given wt of } A}{\text{Molecular wt. of } A}$

no. of moles of $B = \dfrac{\text{given wt. of } B}{\text{Molecular wt. of } B}$

∴ Molecular weight of benzene



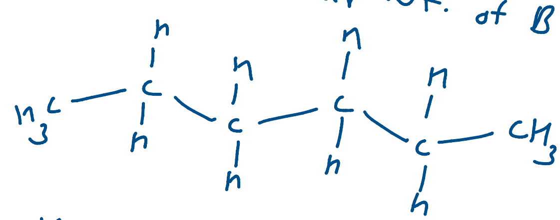
$C_6H_6 = (12 \times 6) + (1 \times 6)$

$\hookrightarrow = 78\ gm\,mol^{-1}$

$n_A = \dfrac{100\ \cancel{gm}}{78\ \cancel{gm}\,mol^{-1}}$

$n_A = 1.2820\ mol$

Hexane



M. wt = $C_6H_{14} = (12 \times 6) + (1 \times 14) = 86\ gm\,mol^{-1}$

$\therefore n_B = \dfrac{10\ \cancel{gm}}{86\ \cancel{gm}\,mol^{-1}} = 0.1162\ mol$

$\therefore x_B = \dfrac{n_B}{n_A + n_B} = \dfrac{0.1162}{1.2820 + 0.1162}$

$x_B = 0.0831$

$\therefore \Delta T_f = RT^{*2}$ ...

$$\therefore \Delta T = \frac{RT^{*2}}{\Delta H_f} x_B$$

$$= \frac{8.314 \, J \, K^{-1} mol^{-1} \times (278.53 \, K)^2 \, K^2}{9.836 \times 10^3 \, J \, mol^{-1}} \times 0.0831$$

$$\boxed{\Delta T = 5.4492 \, K}$$

When 5.25 g of a substance is dissolved in 565 g of benzene at 25°C, the boiling point is raised by 0.625°C. Evaluate the molecular weight of the substance. [K_b = 2.53 K Kg mol^{-1}].

Formula :

$\Delta T_b = K_b \times b$

weight of solvent = 565 gm = 0.565 kg

weight of solute = 5.25 gm

Given $\Delta T_b = 0.625°C = 0.625 \, K$ (bcz, diff.)

$K_b = 2.53 \, K \, kg \, mol^{-1}$

$$b = \text{molality of solute} = \frac{\text{no. of moles of solute.}}{\text{weight of Solvent in kg.}}$$

$$b = \frac{\text{wt. of solute / M.wt. of solute}}{0.565 \, kg.}$$

$$b = \frac{\frac{5.25 \, gm}{\text{M.wt. of solute}}}{0.565 \, kg.} =$$

$$\boxed{b = \frac{5.25 \, gm}{\text{M.wt. of solute} \times 0.565 \, kg}}$$

$$\Delta T_b = K_b \times b$$

$$b = \frac{\Delta T_b}{K_b}$$

$$\frac{5.25 \text{ gm}}{\text{M. wt. of solute} \times 0.565 \text{ kg}} = \frac{0.625 \text{ K}}{2.53 \text{ K kg mol}^{-1}}$$

$$\therefore \text{M. wt. of solute} = \frac{5.25 \text{ gm} \times 2.53 \text{ K kg mol}^{-1}}{0.565 \text{ kg} \times 0.625 \text{ K}}$$

$$= 37.61 \text{ gm mol}^{-1}$$

Estimate the molar solubility of oxygen in water at 25°C and partial pressure of 160 torr. (Henry's constant K = 3.3 × 10^7 torr).

$b_B \propto x_B \propto n_B$

ie

$$b_B = \frac{n_B}{\text{kg of solvent}}$$

Given :-

$P_B = 160$ torr

$K_B = 3.3 \times 10^7$ torr

b_B = molality of solute (mol kg^{-1})

formula :- $P_B = K_B b_B$ ← Henry's law → $P_B = K_B x_B \Rightarrow x_B = \frac{n_B}{n_A + n_B}$

$$b_B = \frac{P_B}{K_B} = \frac{160 \text{ torr}}{3.3 \times 10^7 \text{ torr kg mol}^{-1}} = 4.84 \times 10^{-6} \text{ mol kg}^{-1}$$

Molar solubility expressed in mol lit^{-1}

density of water = 1 gm/ml = 1 kg lit^{-1}

ie 1 kg = 1 Lit.

$\therefore$ molar solubility = 4.84×10^{-6} mol lit^{-1}

$= 0.00484 \times 10^{-3}$ mmol lit^{-1}

$\hookrightarrow \quad = 0.00484 \times 10^{-3}$ mmol lit^{-1}

A water alcohol mixture is 40% in alcohol by mass, the density of water is 1 gram/cc and density of alcohol is 0.785 gram/cc. Find the total volume of 1 kg mixture [Given : Partial molar volume of water = 17.5 cc mole^{-1}, and partial molar volume of ethanol = 55.0 cc mole^{-1}].

A = solvent = water

B = solute = alcohol

Total volume of solution

$$V = n_A V_A + n_B V_B$$

Given

$V_A = 17.5$ cm^3 mol^{-1}

$V_B = 55.0$ cm^3 mol^{-1}

We have to find n_A & n_B

40% alcohol(B) & 60% water (A)

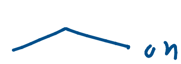
$$\text{no. of moles of A} = \frac{\text{given weight of A gm}}{\text{M. wt. of A gm mol}^{-1}} = \text{mol}$$

Total 1 kg, 60% water = 600 gm water

$$\hookrightarrow \frac{600 \text{ gm}}{18 \text{ gm mol}^{-1}} = 33.33 \text{ mol.}$$

$$\text{no. of moles of B} = \frac{\text{given wt of B gm}}{\text{M. wt of B in gm mol}^{-1}}$$

Total 1 kg, 40% alcohol = 400 gm

M. wt of alcohol =  = $(12\times 2) + 16 + 6 = 56$ gm mol^{-1}

M. wt of alcohol = ⌃⌄OH $= (12\times 2) + 16 + 6 = 46$ gm mol^{-1}

$= \frac{400 \text{ gm}}{46} = 8.69$ mol

$\therefore V = n_A V_A + n_B V_B$

$= 33.33 \times 17.5 + 8.69 \times 55.0$

$= 1061.225$ ml

At 25°c the density of 50% by mass of ethanol-water mixture is 914 kg/m^3. Find the Partial molar volume of ethanol.

[Partial Molar volume of water=17.4 cm^3 mole^{-1}]

Given, $V_A = 17.5$ cm^3 mol^{-1} = water

$V_B = ?$ = ethanol.

$V = n_A V_A + n_B V_B$

$\therefore V_B = \frac{V - n_A V_A}{n_B}$

Let's take 100 cm3 of soln as convenient sample.

$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$

$\therefore \text{Mass} = \text{Density} \times \text{volume}$

$= 914 \text{ kg m}^{-3} \times 100 \text{ cm}^3$

Mass $= 0.914$ gm cm^{-3} $\times 100$ cm^3

$$\text{Mass} = 0.914 \text{ gm cm}^{-3} \times 100 \text{ cm}^3$$

$$\text{Total Mass} = 91.4 \text{ gm}$$

Now weight of water & weight of ethanol is (Given that 50%.)

ie $0.5 \times 91.4 = 45.7$ gm

$$\text{No. of moles of } H_2O = \frac{\text{given wt}}{\text{M. wt.}}$$

$$n_A = \frac{45.7 \text{ gm}}{18 \text{ gm mol}^{-1}}$$

$$n_A = 2.538 \text{ mol}$$

$0.5 \times 91.4 = 45.7$ gm

$$n_B = \frac{45.7 \text{ gm}}{\text{M. wt.}} = \frac{45.7 \text{ gm}}{46 \text{ gm mol}^{-1}}$$

$$n_B = 0.993 \text{ mol}$$

$$\therefore V_B = \frac{V - n_A V_A}{n_B} = \frac{100 - 2.538 \times 17.5}{0.993}$$

$$V_B = 55.97 \text{ cm}^3 \text{ mol}^{-1}$$