

## 2. SOLUTION

2.16 Heptane and octane form an ideal solution. At 373 K, the vapour pressures of the two liquid components are 105.2 kPa and 46.8 kPa respectively. What will be the vapour pressure of a mixture of 26.0 g of heptane and 35.0 g of octane?  
Sol.

Molar mass of heptane ( $C_7H_{16}$ )

$$= 7 \times 12 + 16 = 100 \text{ g mol}^{-1}$$

Molar mass of octane ( $C_8H_{18}$ )

$$= 8 \times 12 + 18 = 114 \text{ g mol}^{-1}$$

Moles of heptane present in mixture

$$= \frac{26.0}{100} = 0.26 \text{ mol}$$

Moles of octane present in mixture

$$= \frac{35.0}{114} = 0.307 \text{ mol}$$

Mole fraction of heptane  $x_H$

$$= \frac{0.26}{0.26 + 0.307} = 0.458$$

Mole fraction of octane,  $x_O = (1 - 0.458) = 0.542$

Vapour pressure of heptane  $= x_H \times P^\circ$

$$= 0.458 \times 105.2 \text{ kPa} = 48.18 \text{ kPa}$$

Vapour pressure of octane  $= x_O \times P^\circ$

$$= 0.542 \times 46.8 \text{ kPa} = 25.36 \text{ kPa}$$

Vapour pressure of mixture

$$= 48.18 + 25.36 = 73.54 \text{ kPa}$$

2.17 The vapour pressure of water is 12.3 kPa at 300 K. Calculate vapour pressure of 1 molal solution of a non-volatile solute in it

**Sol.** 1 molal solution of solute means 1 mole of solute in 1000g of the solvent.

Molar mass of water (solvent) =  $18 \text{ g mol}^{-1}$

$$\therefore \text{Moles of water} = \frac{1000}{18} = 55.5 \text{ moles.}$$

$$\therefore \text{Mole fraction of solute} = \frac{1}{1 + 55.5} = 0.0177$$

$$\text{Now, } \frac{P^{\circ} - P_s}{P^{\circ}} = x_2$$

$$\frac{12.3 - P_s}{12.3} = 0.0177$$

$$\Rightarrow P_s = 12.08 \text{ kPa}$$

**2.18** Calculate the mass of a non-volatile solute (molar mass  $40 \text{ g mol}^{-1}$ ) which should be dissolved in 114 g octane to reduce its vapour pressure to 80%.

**Sol.**

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$$P_s = 80\% \text{ of } P^\circ$$

$$= \frac{80}{100} P^\circ = 0.8 P^\circ$$

Let  $W$ g of solute is present in mixture.

$$\text{Moles of solute present} = \frac{W}{40} \text{ moles}$$

$$\begin{aligned} \text{Molar mass of octane, } C_8H_{18} \\ = 8 \times 12 + 18 = 114 \text{ g mol}^{-1} \end{aligned}$$

$$\therefore \text{Moles of octane} = \frac{114}{114} = 1 \text{ mol}$$

$$\text{Now, } \frac{P^\circ - P_s}{P^\circ} = x_2 = \frac{W/40}{\frac{W}{40} + 1}$$

$$\frac{P^\circ - 0.80 P^\circ}{P^\circ} = \frac{W/40}{W/40 + 1}$$

$$1 - 0.80 = \frac{W \times 40}{40(W + 40)} = \frac{W}{W + 40}$$

$$0.20 = \frac{W}{W + 40}$$

$$0.2 W + 8 = W$$

$$8 = W(1 - 0.2)$$

$$8 = 0.8 W$$

$$\therefore W = \frac{8}{0.8} = 10 \text{g.}$$

2.19 A solution containing 30g of non-volatile solute exactly in 90 g of water has a vapour pressure of 2.8 kPa at 298 K. Further, 18g of water is then added to the solution and the new vapour pressure becomes 2.9 kPa at 298 K. Calculate  
(i) molar mass of the solute.

(ii) vapour pressure of water at 298 K.

Sol. Let the molar mass of solute =  $M$ g mol<sup>-1</sup>

∴ Moles of solute present

$$= \frac{30 \text{ g}}{M \text{ g mol}^{-1}} = \frac{30}{M} \text{ mol}$$

Moles of solvent present,  $(n_1) = \frac{90}{18} = 5$  moles.

$$\therefore \frac{P^\circ - P_s}{P^\circ} = \frac{n_2}{n_1 + n_2}$$

$$\frac{P^\circ - 2.8}{P^\circ} = \frac{30/M}{5 + 30/M}$$

$$1 - \frac{2.8}{P^\circ} = \frac{30}{(5M + 30)}$$

$$1 - \frac{30}{5M + 30} = \frac{2.8}{P^\circ}$$

$$1 - \frac{6}{M + 6} = \frac{2.8}{P^\circ}$$

$$\frac{M + 6 - 6}{M + 6} = \frac{2.8}{P^\circ}$$

$$\frac{M}{M + 6} = \frac{2.8}{P^\circ}$$

$$\frac{P^\circ}{2.8} = 1 + \frac{6}{M} \quad \dots(i)$$

After adding 18 g of water,  
Moles of water becomes

$$= \frac{90 + 18}{18} = \frac{108}{18} = 6 \text{ moles}$$

$$\therefore \frac{P^\circ - P_s}{P^\circ} = \frac{30/M}{6 + 30/M}$$

$P_s$  New vapour pressure = 2.9 kPa

$$\frac{P^\circ - 2.9}{P^\circ} = \frac{30M}{M(6M + 30)} = \frac{5}{M + 5}$$

$$1 - \frac{2.9}{P^\circ} = \frac{5}{M + 5}$$

$$1 - \frac{5}{M + 5} = \frac{2.9}{P^\circ}$$

$$\frac{M + 5 - 5}{M + 5} = \frac{2.9}{P^\circ}$$

$$\frac{P^\circ}{2.9} = \frac{M + 5}{M} \Rightarrow = 1 + \frac{5}{M}$$

$$\frac{P^\circ}{2.9} = 1 + \frac{5}{M} \quad \dots(ii)$$

Dividing equation (i) by (ii), we get,

$$\frac{2.9}{2.8} = \frac{1 + 6/M}{1 + 5/M}$$

$$2.9 \left(1 + \frac{5}{M}\right) = 2.8 \left(1 + \frac{6}{M}\right)$$

$$2.9 + \frac{2.9 \times 5}{M} = 2.8 + \frac{2.8 \times 6}{M}$$

$$2.9 + \frac{14.5}{M} = 2.8 + \frac{16.8}{M}$$

$$0.1 = \frac{16.8}{M} - \frac{14.5}{M} = \frac{2.3}{M}$$

$$M = \frac{2.3}{0.1}$$

$$M = 23 \text{ g mol}^{-1}$$

Putting  $M = 23$ , in equation (i), we get,

$$\frac{P^\circ}{2.8} = 1 + \frac{6}{23} = \frac{29}{23}$$

$$P^\circ = \frac{29}{23} \times 2.8 = 3.53 \text{ kPa}$$

2.20 A 5% solution (by mass) of cane sugar in water has freezing point of 271 K. Calculate the freezing point of 5% glucose in water if freezing point of pure water is 273.15 K.

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Sol. Mass of sugar in 5% (by mass) solution means 5g in 100g of solvent (water)

Molar mass of sugar =  $342 \text{ g mol}^{-1}$

$$\text{Molality of sugar solution} = \frac{5 \times 1000}{342 \times 100} = 0.146$$

$$\therefore \Delta T_f \text{ for sugar solution} = 273.15 - 271 = 2.15^\circ$$

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

$$\Delta T_f = K_f \times 0.146 \Rightarrow K_f = 2.15/0.146$$

Molality of glucose solution

$$= \frac{5}{180} \times \frac{1000}{100} = 0.278$$

(Molar mass of glucose =  $180 \text{ g mol}^{-1}$ )

$$\Delta T_f = K_f \times m = \frac{2.15}{0.146} \times 0.278 = 4.09^\circ$$

$$\therefore \text{Freezing point of glucose solution} \\ = 273.15 - 4.09 = 269.06 \text{ K.}$$

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