SOLVED PROBLEMS ON LOWERING OF VAPOUR PRESSURE

Example 1. A solution containing 6.0 gram of benzoic acid in 50 gram of ether ($C_2H_5OC_2H_5$) has a vapour pressure equal to 5.466×10^4 Nm^{-2} at 300 K. Given that vapour pressure of ether at the same temperature is 5.893×10^4 NM^{-2}, calculate the molecular mass of benzoic acid.

Solution. Vapour pressure of ether (Solvent) = $P^\circ = 5.893 \times 10^4$ Nm^{-2}

Vapour pressure of ether solution = $P = 5.466 \times 10^4$ Nm^{-2}

Molecular mass of solvent ($C_2H_5 - O - C_2H_5$) (M) = 74

Mass of solute (benzoic acid) w = 6 grams

Mass of solvent (ether) W = 50 grams

Let molecular mass of solute (benzoic acid) = m

Substituting the values in the relation

$$\frac{P_A^\circ - P}{P^\circ} = \frac{w}{m} \times \frac{M}{W}$$

$$\frac{5.893\times10^4 - 5.466\times10^4}{5.893\times10^4} = \frac{6\times74}{m\times50}$$

$$\frac{0.427\times10^4}{5.893\times10^4} = \frac{6\times74}{m\times50}$$

$$\frac{0.427}{5.893} = \frac{6\times74}{m\times50}$$

$$m = \frac{6\times74\times5.893}{50\times0.427}$$

$$m = 122.55$$

i.e., the molecular mass of solute (benzoic acid) = 122.55 amu.

Example 2. The vapour pressure of water at 293 K is 17.51 mm, lowering of vapour pressure of sugar solution is 0.0614 mm.

Calculate

(a) Relative lowering of vapour pressure.

(b) Vapour pressure of the solution.

(c) Mole fraction of water.

Solution. Vapour pressure of solvent (water) = 17.51

Let Vapour pressure of the solution= P (to be calculated)

$\therefore$ Lowering of Vapour pressure $= P^\circ - P = 0.0614$ mm

(*a*) $\therefore$ Relative lowering of Vapour pressure $= \frac{p^\circ - p}{p^\circ} = \frac{0.0614}{17.51} = 0.00351$

(*b*) Vapour pressure of the solution $P = P^\circ - (P^\circ - P)$

$= 17.51 - (0.0614) = 17.4486$ mm

Now according to Raoult's Law

$$\frac{p^\circ - p}{p^\circ} = \text{mole fraction of the solute}$$

$$\frac{p^\circ - p}{p^\circ} = \frac{n_1}{n_1 + n_2} = x_2$$

$\therefore$ mole fraction of the solute $= \dfrac{p^\circ - p}{p^\circ} = \dfrac{0.0614}{17.51} = 0.00351$

(*c*) Hence, mole fraction of the solvent = (1 – 0.00351) = 0.99649

Mole fraction of water = 0.99649

Example 3. The Vapour pressure of a 5% aqueous solution of non-volatile organic substances at 373 K is 745 mm. Calculate the molecular mass of the solute.

Solution. Weight of non-volatile organic solute, $w = 5$ g

Weight of solvent (water), $W = 95$ g

Molecular mass of solvent (water) $M = 18$

Molecular mass of non-volatile solute $m = ?$

P°, the Vapour pressure of the pure solvent (water) at 373 K = 760 mm

Vapour pressure of the solution $P = 745$ mm

Substituting the values in the relation,

$$\frac{p^\circ - p}{p^\circ} = \frac{w}{m} \times \frac{M}{W}$$

$$\frac{760 - 745}{760} = \frac{5 \times 18}{m \times 95}$$

or $$m = \frac{5 \times 18 \times 760}{15 \times 95} = 48$$

Example 4. At 298 K, the vapour pressure of water is 23.75 mm of Hg. Calculate the vapour pressure at the same temperature over 5% aqueous solution of urea ($NH_2\ CONH_2$).

Solution. This solution may be considered as a dilute solution and the approximate relation given below may be used

$$\frac{P_A^\circ - P_A}{P_A^\circ} = \frac{wM}{mW}$$

In the present case $P_A^\circ = 23.75$

$w = 5$ g Therefore $W = 100 - 5 = 95$ g

$M = 18$, $m = 60$ (mol. wt of urea)

Substituting these values in the equation above

$$\frac{23.75 - P_A}{23.75} = \frac{5 \times 18}{60 \times 95} \quad \text{or} \quad P_A = 23.375 \text{ mm.}$$