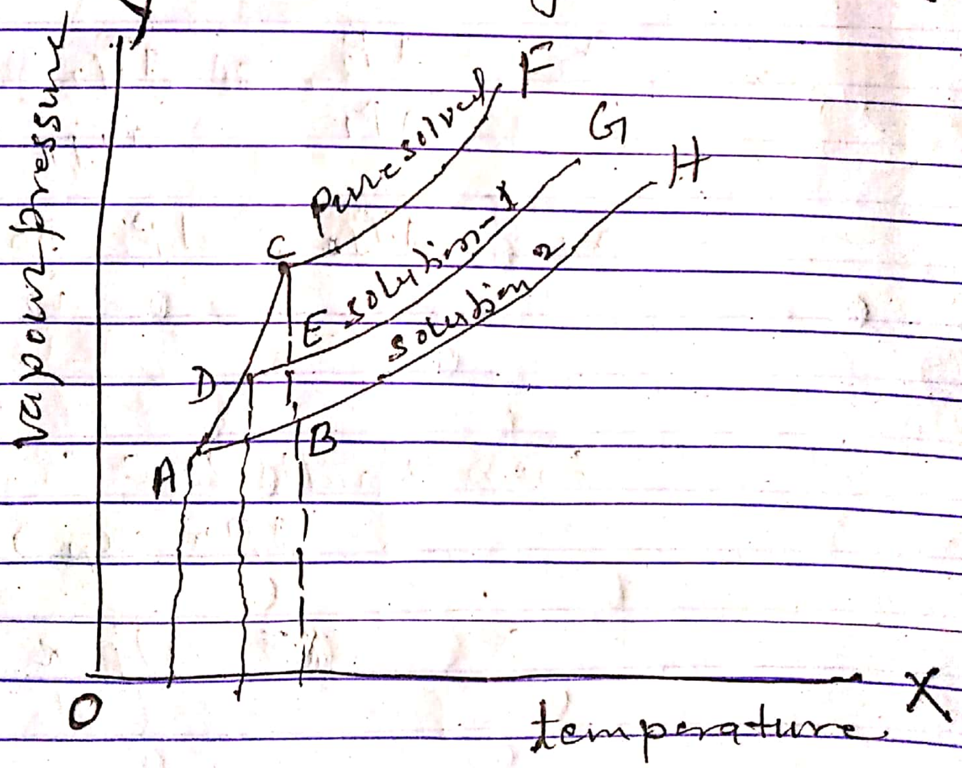
B.Sc. I. Paper IA

Depression of freezing point

The freezing point of a substance is a temperature at which liquid freezes to solid. At this temperature solid and its liquid form co-exit. When non-volatile solute dissolve in solvent, vapour ~~vapo~~ pressure of solvent in solution decreases and therefore the vapour pressure of solid and liquid is equal at lower temperature. Hence there is depression of freezing point of the solvent in solution.

This is illustrated by below graph of vapour pressure against temperature.



Curve CE, DG and AH are the curve of pure solvent, solution 1 and solution 2 of vapour pressure verses temperature. T_f is freezing point of solvent, T_{f_1} and T_{f_2} are the freezing point of solution 1 and solution -2.

For very dilute solution curve are considered to be straight line and hence for

ΔABC and DCE

$$\frac{BC}{CE} = \frac{AB}{ED}$$

or;
$$\frac{P-P_2}{P-P_2} = \frac{T_f - T_{f2}}{T_f - T_{f1}}$$

or
$$\frac{\Delta P_2}{\Delta P_1} = \frac{\Delta T_{f2}}{\Delta T_{f1}}$$

or; $\Delta T_f \propto \Delta P$, Depression of freezing point is proportional to lowering of vapour pressure.

From Raults law for dilute solution.
$\Delta P \propto x_B$ i.e mole fraction of solute.

or $\Delta T_f \propto x_B$ —— (1)

mole fraction of solute $x_B = \dfrac{\frac{w_B}{M_B}}{\frac{w_B}{M_B} + \frac{w_A}{M_A}}$ ——— (ii)

Where w_B and M_B are mass and molecular mass of solute and w_A and M_A are the mass and molecular mass of solvent

As $\frac{w_B}{M_B} <<< \frac{w_A}{M_A}$

∴ equation (ii) will be

$$x_B = \frac{w_B/M_B}{w_A/M_A}$$

or $x_B = n_B \cdot \frac{M_A}{w_A}$

or $x_B = m \cdot M_A$ ——— (iii)

where m = molality of the solution (i.e mole per 1000 gram of solvent)

From equation (i) and (iii)

$$\Delta T_f \propto m \cdot M_A$$

or $\Delta T_f = K \cdot m \cdot M_A$ ——— (iv)

or $\boxed{\Delta T_f = K_f \cdot m}$ where $K_f = K \cdot M_A$

i.e perportionality const × ~~molality~~ molecular mass of solvent

K_f is called the molal freezing point depression constant

If molality of solution i.e $m = 1$

then equation (iv) will be

$$\Delta T_f = K_f \cdot 1 = K_f \quad \text{(V)}$$

i.e. Molal freezing point ~~depression~~ dipression is depression of freezing point for one molal solution.

As molality $m = \frac{1000 \cdot W_B}{M_B \cdot W_A}$

hence putting value of m in equation (iv) we get:

$$\Delta T_f = K_f \frac{1000 W_B}{M_B \cdot W_A}$$

$$\text{or, } M_B = \frac{1000 K_f W_B}{W_A}$$

When W_B = solute mass, W_A = mass of solvent and K_f is known, the molecular mass of non volatile solute will be calculated.

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