AP CHEMISTRY

TOPIC 12: SOLUTIONS, PART B, EXAMPLES

Day 135:

- Colligative Properties (Boiling Point Elevation and Freezing Point Depression)

Boiling-Point Elevation Constants (K_b) and Freezing-Depression Constants (K_f) for Several Solvents

Solvent	Boiling Point (°C)	K_b (°C · kg/mol)	Freezing Point (°C)	K_f (°C · kg/mol)
Water (H_2O)	100.0	0.51	0	1.86
Carbon tetrachloride (CCl_4)	76.5	5.03	−22.99	30.
Chloroform ($CHCl_3$)	61.2	3.63	−63.5	4.70
Benzene (C_6H_6)	80.1	2.53	5.5	5.12
Carbon disulfide (CS_2)	46.2	2.34	−111.5	3.83
Ethyl ether ($C_4H_{10}O$)	34.5	2.02	−116.2	1.79
Camphor ($C_{10}H_{16}O$)	208.0	5.95	179.8	40.

Example #1:

A solution is prepared by dissolving 4.9 grams sucrose ($C_{12}H_{22}O_{11}$) in 175 grams of water. Calculate the boiling point of this solution. Sucrose is a nonelectrolyte.

$$\Delta T_b = i\, k_b\, molality$$

$C_{12}H_{22}O_{11} \rightarrow C_{12}H_{22}O_{11}$, Van't Hoff factor (i) = 1

$$mol\ C_{12}H_{22}O_{11} = \frac{4.9\ g}{} \times \frac{1\ mol\ C_{12}H_{22}O_{11}}{222.1738\ g} = 0.02205\ mol$$

$$molality = \frac{0.02205\ mol}{0.175\ kg} = 0.126\ \frac{mol}{kg}$$

$$\Delta T_b = (1)\left(0.51 \frac{^0C \cdot kg}{mol}\right)\left(0.126 \frac{mol}{kg}\right) = 0.0643\ ^0C$$

B.P. for water = 100 ^{0}C + 0.0643 ^{0}C = 100.0643 ^{0}C

Example #2:

Calculate the freezing point for water if 320.0 grams of solid calcium nitrate is added to 2500 mL of water.

$$\Delta T_f = i\, k_f\, molality$$

$Ca(NO_3)_2 \rightarrow Ca^{+2} + 2\ NO_3^{-1}$, Van't Hoff factor (i) = 3

$$mol\ Ca(NO_3)_2 = \frac{320\ g}{} \times \frac{1\ mol\ Ca(NO_3)_2}{164.1\ g} = 1.95\ mol$$

$$molality = \frac{1.95\ mol}{2.500\ kg} = 0.780\ \frac{mol}{kg}$$

$$\Delta T_f = (3)\left(1.86 \frac{^0C \cdot kg}{mol}\right)\left(0.780 \frac{mol}{kg}\right) = 4.35\ ^0C$$

F.P. for water = 0 ^{0}C – 4.35 ^{0}C = - 4.35 ^{0}C

Example #3:

Calculate the freezing point and boiling point for chloroform (polar) if 75 grams of lithium phosphate (dissociates 100% in chloroform) is placed into 23.2 moles of chloroform.

$$\Delta T_f = i\, k_f\, molality$$

$Li_3PO_4 \rightarrow 3\ Li^{+1} + PO_4^{-3}$, Van't Hoff factor (i) = 4

$$mol\ Li_3PO_4 = \frac{75\ g}{} \times \frac{1\ mol\ Li_3PO_4}{115.797\ g} = 0.6477\ mol$$

$$kg\ CHCl_3 = \frac{23.2\ mol\ CHCl_3}{} \times \frac{119.3669\ g}{2\ mol\ CHCl_3} \times \frac{1\ kg}{1000\ g} = 1.385\ kg$$

$$molality = \frac{0.6477\ mol}{1.385\ kg} = 0.468\ \frac{mol}{kg}$$

$$\Delta T_b = (4)\left(3.63 \frac{^0C \cdot kg}{mol}\right)\left(0.468 \frac{mol}{kg}\right) = 6.795\ ^0C$$

B.P. for water = 61.2 ^{0}C + 6.795 ^{0}C = 68.00 ^{0}C

$$\Delta T_f = (4)\left(4.70 \frac{^0C \cdot kg}{mol}\right)\left(0.468 \frac{mol}{kg}\right) = 8.80\ ^0C$$

F.P. for water = -63.5 ^{0}C - 8.80 ^{0}C = -72.30 ^{0}C