

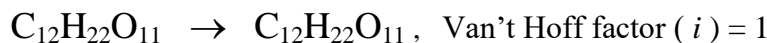
- Colligative Properties ( Boiling Point Elevation and Freezing Point Depression )

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 <sub>2</sub> O)	100.0	0.51	0	1.86
Carbon tetrachloride (CCl <sub>4</sub> )	76.5	5.03	-22.99	30.
Chloroform (CHCl <sub>3</sub> )	61.2	3.63	-63.5	4.70
Benzene (C <sub>6</sub> H <sub>6</sub> )	80.1	2.53	5.5	5.12
Carbon disulfide (CS <sub>2</sub> )	46.2	2.34	-111.5	3.83
Ethyl ether (C <sub>4</sub> H <sub>10</sub> O)	34.5	2.02	-116.2	1.79
Camphor (C <sub>10</sub> H <sub>16</sub> O)	208.0	5.95	179.8	40.

Example #1:

A solution is prepared by dissolving 4.9 grams sucrose ( C<sub>12</sub>H<sub>22</sub>O<sub>11</sub> ) in 175 grams of water. Calculate the boiling point of this solution. Sucrose is a nonelectrolyte.

$$\Delta T_b = i k_b \text{ molality}$$



$$\text{mol C}_{12}\text{H}_{22}\text{O}_{11} = \frac{4.9 \text{ g}}{222.1738 \text{ g}} \times \frac{1 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}}{1} = 0.02205 \text{ mol}$$

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

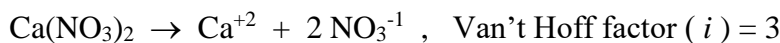
$$\Delta T_b = (1) \left( 0.51 \frac{^\circ\text{C} \cdot \text{kg}}{\text{mol}} \right) \left( 0.126 \frac{\text{mol}}{\text{kg}} \right) = 0.0643 \text{ }^\circ\text{C}$$

$$\text{B.P. for water} = 100 \text{ }^\circ\text{C} + 0.0643 \text{ }^\circ\text{C} = 100.0643 \text{ }^\circ\text{C}$$

Example #2:

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

$$\Delta T_f = i k_f \text{ molality}$$



$$\text{mol Ca}(\text{NO}_3)_2 = \frac{320 \text{ g}}{164.1 \text{ g}} \times \frac{1 \text{ mol Ca}(\text{NO}_3)_2}{1} = 1.95 \text{ mol}$$

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

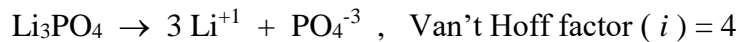
$$\Delta T_f = (3) \left( 1.86 \frac{^\circ\text{C} \cdot \text{kg}}{\text{mol}} \right) \left( 0.780 \frac{\text{mol}}{\text{kg}} \right) = 4.35 \text{ }^\circ\text{C}$$

$$\text{F.P. for water} = 0 \text{ }^\circ\text{C} - 4.35 \text{ }^\circ\text{C} = -4.35 \text{ }^\circ\text{C}$$

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.

$$\Delta T_f = i k_f \text{ molality}$$



$$\text{mol Li}_3\text{PO}_4 = \frac{75 \text{ g}}{115.797 \text{ g}} \times \frac{1 \text{ mol Li}_3\text{PO}_4}{1} = 0.6477 \text{ mol}$$

$$\text{kg CHCl}_3 = \frac{23.2 \text{ mol CHCl}_3}{2 \text{ mol CHCl}_3} \times \frac{119.3669 \text{ g}}{1000 \text{ g}} \times \frac{1 \text{ kg}}{1} = 1.385 \text{ kg}$$

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

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

$$\text{B.P. for water} = 61.2 \text{ }^\circ\text{C} + 6.795 \text{ }^\circ\text{C} = 68.00 \text{ }^\circ\text{C}$$

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

$$\text{F.P. for water} = -63.5 \text{ }^\circ\text{C} - 8.80 \text{ }^\circ\text{C} = -72.30 \text{ }^\circ\text{C}$$