Problem 13-09 Freezing point depression of electrolytes and non-electrolytes solutions

Aqueous solution of 10.6 g of NaCl (on dissolving dissociates completely, M_{NaCl} = 58 g mol^{-1}) in 849.8 g of water freezes at the temperature of –0.8 °C. Calculate the minimum amount of ethylene glycol (not dissociating on dissolving, M_{EG} = 62 g mol^{-1}) which you must dissolve in 15 kg of water to prevent the freezing at –10 °C.

[m_2 = 5 kg]

Solution:

$\Delta T_f = -i\ K_K \cdot \underline{m}_2$, molality: $\underline{m}_2 = \dfrac{m_2}{M_2 \cdot m_1}$ (m_2 … mass of the dissolved substance)

Calculation of K_f of water from the data on NaCl:

NaCl: m_{NaCl} = 10.6 g NaCl
$(m_{H2O})_1$ = 849.8 g = 0.8498 kg H_2O
M_{NaCl} = 62 g mol^{-1}

$$K_{K,\,NaCl} = -\frac{(\Delta T_f)_{NaCl}}{i \cdot \underline{m}_{NaCl}}$$

where $\underline{m}_{NaCl} = \dfrac{m_{NaCl}}{M_{NaCl} \cdot m_{H_2O}} = \dfrac{10{,}6}{58 \cdot 0{,}8498} = 0.21506_{07}$ mol kg^{-1}

$$K_K = -\frac{-0.8}{2 \cdot 0.215_{0607}} = 1.86 \text{ K kg mol}^{-1}$$

Ethylene glycol: m_{EG} = ?
$(m_{H2O})_2$ = 15 kg
M_{EG} = 62 g mol^{-1}

$\Delta T_{f,\,EG} = -10$ K = $K_{K,EG} \cdot \underline{m}_{EG}$

$$\underline{m}_{EG} = \frac{m_{EG}}{62 \cdot 10} = \frac{m_{EG}}{620} = \frac{\Delta T_{f,EG}}{K_{K,EG}}$$

$$m_2 = \frac{\Delta T_{f,EG}}{K_{K,EG}} \cdot 62 \cdot 15 = \frac{10}{1.86} \cdot 62 \cdot 15 = 5000 \text{ g} = 5 \text{ kg}$$