Problem 13-02 Vapour pressure lowering, molar mass of solute

Dissolution of 3.64 g of nonvolatile substance in 400 g of chloroform (M = 119.38 g mol^{-1}) at the temperature of 15 °C will reduce the chloroform vapour pressure by 55 Pa. Calculate the vapour pressure above the solution and molar mass of the solute. The saturated vapour pressure of chloroform is given by Antoine equation:

$$\log\left(p^{\mathrm{s}}/\mathrm{kPa}\right) = A - \frac{B}{C + (t/°\mathrm{C})}$$

A	B	C
6.23638	1232.79	230.213

[p_1 = 16.124 Pa; M_2 = 318.43 g mol^{-1}]

Solution:

t = 15°C

$$\log\left(p^{\mathrm{s}}/\mathrm{kPa}\right) = A - \frac{B}{C + (t/°\mathrm{C})} = 6.23638 - \frac{1232.79}{230.213 + 15} = 1.208955$$

p^{s} = 16.17912 kPa

$$\Delta p_1 = p_1^{\mathrm{s}} - p_1 = x_2 \cdot p_1^{\mathrm{s}}$$

$$x_2 = \frac{\Delta p_1}{p_1^{\mathrm{s}}} = \frac{55 \cdot 10^{-3}}{16.17912} = 0.0034$$

$$p_1 = p_1^{\mathrm{s}} \cdot (1 - x_2) = 16.17912 \cdot (1 - 0.0034) = 16.12411 \text{ kPa}$$

m_1 = 400 g , M_1 = 119.38 g mol^{-1}

m_2 = 6 g , M_2 = ?

$$x_2 = \frac{n_2}{n_2 + m_1/M_1}$$

$$\frac{n_2 + m_1/M_1}{n_2} = \frac{1}{x_2}$$

$$1 + \frac{m_1/M_1}{n_2} = \frac{1}{x_2}$$

$$n_2\left(= \frac{m_2}{M_2}\right) = \frac{m_1/M_1}{1/x_2 - 1} \quad \Rightarrow \quad M_2 = \frac{m_2 \cdot M_1}{m_1} \cdot \left(\frac{1}{x_2} - 1\right) = \frac{3.64 \cdot 119.38}{400} \cdot \left(\frac{1}{0.0034} - 1\right)$$

M_2 = 318.43 g mol^{-1}