Question

What is the boiling point of a solution prepared by dissolving 245 g of $CaCl_2$ into 2055 mL of water?

Solution

The boiling point elevation can be predicted using the equation (Raoult law):

$$\Delta T = K_b \cdot m \cdot i \,,$$

where ΔT – change in boiling point, i – number of moles of ions in the solution per mole of dissolved substance, m – molality of the solution, and K_b – molal boiling point constant.

Molal boiling point constant for water – $K_b = 0.51\ ^{o}C \cdot kg/mol$

$CaCl_2$ in water solution dissociates as follows:

$$CaCl_2 \leftrightarrow Ca^{2+} + 2Cl^{-}$$

So, the number of moles of ions in the solution per mole of $CaCl_2$ is equal to three, i.e. $i = 3$.

Molality of the solution is defined as number of moles of dissolved substance ($CaCl_2$ in this case) per 1 kg of solvent (water in this case):

$$m = \frac{n_{CaCl_2}}{m_w} \,,$$

where n_{CaCl_2} – number of moles of $CaCl_2$.

Number of moles of $CaCl_2$ may be calculated as a quotient of mass to molar mass. Molar mass of $CaCl_2$ – $M_{CaCl_2} = 110.98$ g/mole.

$$n_{CaCl_2} = \frac{m_{CaCl_2}}{M_{CaCl_2}} = \frac{245}{110.98} = 2.21\ moles$$

Mass of water is calculated as product of its volume and density ($\rho_w = 1.0$ g/mL)

$$m_w = V_w \cdot \rho_w = 2055 \cdot 1.0 = 2055\ g = 2.055\ kg$$

So, the solution molality is

$$m = \frac{2.21}{2.055} = 1.07\ moles/kg \,,$$

Now we can calculate the predicted elevation of boiling point:

$$\Delta T = 0.51 \cdot 1.07 \cdot 3 = 1.64\ ^{o}C$$

The boiling point of the solution is by ΔT greater than pure water boiling point ($T = 100^{o}C$)

$$T_s = T + \Delta T = 100 + 1.64 = 101.64\ ^{o}C$$

Answer: 101.64 ^{o}C