

Answer on Question #57791 - Chemistry - General Chemistry

Task:

A researcher dissolves 2.45g MgCl_2 of 250g of water. Find the boiling point elevation for this solution assuming MgCl_2 dissociates completely and $K_b = 0.512^\circ\text{C}/\text{m}$ for H_2O show all work $T = K_b m$.

Solution:

The extent of boiling-point elevation can be calculated by applying Clausius – Clapeyron relation and Raoult's law together with the assumption of the non-volatility of the solute. The result is that in dilute ideal solutions, the extent of boiling-point elevation is directly proportional to the molal Concentration of the solution according to the equation:

$$\Delta T_b = K_b \times b_B,$$

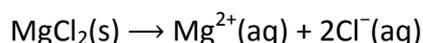
where

- ΔT_b , the boiling point elevation, is defined as $T_{b(\text{solution})} - T_{b(\text{pure solvent})}$;
- K_b , the ebullioscopic constant, which is dependent on the properties of the solvent. It can be calculated as $K_b = RT_b^2 M / \Delta H_v$, where R is the gas constant, and T_b is the boiling temperature of the pure solvent [in K], M is the molar mass of the solvent, and ΔH_v is the heat of vaporization per mole of the solvent.
- b_B is the molality of the solution, calculated by taking dissociation into account since the boiling point elevation is a colligative property, dependent on the number of particles in solution. This is most easily done by using the van't Hoff factor i as $b_B = b_{\text{solute}} \times i$.

The expression for boiling point elevation, when the van't Hoff factor is taken into account, is modified thus:

$$\Delta T_b = iK_b m.$$

The equation for the complete dissociation of MgCl_2 in aqueous solution is



The van't Hoff factor (i) is defined as number of particles produced after dissociation or association number of particles present before dissociation or association number of particles produced after dissociation or association number of particles present before dissociation or association

There is a simple relationship between the degree of dissociation and the van't Hoff factor. If a fraction α of the solute dissociates into n ions, then

$$i = \alpha n + (1 - \alpha) = 1 + \alpha(n - 1)$$

For dissociation MgCl_2 :



Clearly, as one solute particle (one molecule of magnesium chloride) furnishes 3 particles in solution (one magnesium ion and two chloride ions).

Yields $n=3$ ions, so that $i = 1 + 2\alpha$

Because magnesium chloride (MgCl_2) dissociates completely, the degree of dissociation (α) can be taken as unity ($\alpha=1$).

Then, $i = 1 + 2 \times 1 = 3$.

Find the number of moles of solute MgCl_2 :

$$M(\text{MgCl}_2) = 95.211 \text{ g/mol}$$

$$n(\text{MgCl}_2) = \frac{m(\text{MgCl}_2)}{M(\text{MgCl}_2)} = \frac{2.45 \text{ g}}{95.211 \text{ g/mol}} = 0.0257 \text{ moles.}$$

Convert solvent mass from g to kg: $\frac{250 \text{ g}}{1000} = 0.25 \text{ kg}$.

Then calculate the molarity of the solution:

$$\text{Molality (m)} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kilograms}}$$

$$m = \frac{0.0257 \text{ moles}}{0.25 \text{ kg}} = 0.1028 \text{ moles/kg.}$$

And then use the formula

$$\Delta T_b = iK_b m.$$

$$K_b (\text{H}_2\text{O}) = 0.512 \text{ }^\circ\text{C/m};$$

$$i (\text{MgCl}_2) = 3 (\alpha=1);$$

$$m(\text{MgCl}_2, s) = 0.1028 \text{ moles/kg.}$$

$$\Delta T_b = 3 \times 0.512 \times 0.1028 = 0.1579 \text{ }^\circ\text{C}$$

$$\Delta T_b = T_{b(\text{solution})} - T_{b(\text{pure solvent})}$$

$$T_{b(\text{pure solvent})} = 100 \text{ }^\circ\text{C};$$

$$T_{b(\text{solution})} = 0.1579 \text{ }^\circ\text{C} + 100 \text{ }^\circ\text{C} = 100.16 \text{ }^\circ\text{C}.$$

Answer:

$$\Delta T_b = 0.1579 \text{ }^\circ\text{C} = 0.16 \text{ }^\circ\text{C},$$

$$T_{b(\text{solution})} = 0.1579 \text{ }^\circ\text{C} + 100 \text{ }^\circ\text{C} = 100.16 \text{ }^\circ\text{C}.$$