Answer on Question #57791 - Chemistry - General Chemistry

Task:

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

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 $T_{b\ (solution)} - T_{b\ (pure\ solvent)}$;
- K_b, the ebullioscopic constant, which is dependent on the properties of the solvent. It can be calculated as $K_b = RT_b^2M/\Delta H_v$, 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 $b_B = b_{solute} \times i$.

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

$$MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$$

The van't Hoff factor (**i**) is defined as number of particles produced after dissociation or associationnumber of particles present before dissociation or associationnumber of particles produced after dissociation or associationnumber 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 $MgCl_2$:

$$MgCl_2 \longrightarrow Mg^{2+} + 2Cl^-.$$

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 + 2α

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

Then, I = 1 + 2 × 1 = 3.

Find the number of moles of solute $MgCl_2$:

$M(MgCl_2)$ = 95.211 g/mol

$n(MgCl_2) = \frac{m(MgCl_2)}{M(MgCl_2)} = \frac{2.45\ g}{95.211\ g/mol}$ =0.0257 moles.

Convert solvent mass from g to kg: $\frac{250\ g}{1000}$ = 0. 25kg.

Then calculate the molarity of the solution:

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

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

And then use the formula

$$\Delta T_b = iK_b m.$$

Kb (H_2O) = 0.512 °C/m;

i ($MgCl_2$) = 3 (α=1);

m($MgCl_2$,s) = 0.1028 moles/kg.

ΔT_b= 3 × 0.512 × 0.1028 = 0.1579 °C

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

$T_{b\ (pure\ solvent)}$ = 100 °C;

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

Answer:

ΔT_b = 0.1579 °C = 0.16 °C,

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