Math Tutor BOILING AND FREEZING POINTS OF SOLUTIONS

The presence of a nonvolatile solute causes the freezing point of a solution to be lower and the boiling point to be higher than those of the pure solvent. The freezing-point depression, Δt_f, is the amount that the freezing point is lowered. It is calculated by using the formula $\Delta t_f = K_f m$. The boiling-point elevation, Δt_b, is the amount that the boiling point is elevated. It is found by using the equation $\Delta t_b = K_b m$. To determine Δt_f or Δt_b, you need to know its *molal* concentration, m (moles of solute per kilogram of solvent). You also need to know the molal freezing-point constant, K_f, or the molal boiling-point constant, K_b. The values for K_f and K_b depend on the solvent and are given in **Table 2.** When these equations are used for electrolytes, the molality represents the total number of moles of ions in solution.

Problem-Solving TIPS

- Make sure that you find the molal concentration, not the molar concentration.
- For electrolytes, calculate the total number of moles of ions in solution.

SAMPLE

What is the theoretical boiling point of a solution of 247 g of potassium chloride, KCl, dissolved in 2.90 kg of water? Potassium chloride is a strong electrolyte.

First, determine the molality of the KCl that dissolved.

$$\text{mass of solute (g)} \times \frac{1 \text{ mol solute}}{\text{molar mass of solute (g)}} = \text{amount of solute (mol)}$$

$$247 \text{ g KCl} \times \frac{1 \text{ mol KCl}}{74.55 \text{ g KCl}} = 3.31 \text{ mol KCl}$$

$$\text{molality KCl}(m) = \frac{\text{mol solute particles}}{\text{mass of solvent (kg)}} = \frac{3.31 \text{ mol KCl}}{2.90 \text{ kg } H_2O} = 1.14\ m \text{ KCl}$$

Because KCl is an electrolyte, the total moles of ions in solution must now be determined. The equation $KCl(s) \longrightarrow K^+(aq) + Cl^-(aq)$ shows that 1 mol KCl will yield 2 mol of ions.

To find the total molality of particles in solution, multiply the molality of the solute by the moles of ions produced by the dissociation: $2 \times 1.14\ m$ KCl = $2.28\ m$.

Next, use the equation $\Delta t_b = K_b m$, where K_b for water is $0.51°C/m$ and the value for m is 2.28.

$$\Delta t_b = (0.51°C/m)(2.28\ m) = 1.16°C$$

The new boiling point is equal to the sum of the boiling point of the solvent and Δt_b.

$$\text{boiling point of solution} = 100°C + 1.16°C = 101.16°C$$

PRACTICE PROBLEMS

1. What is the freezing point of a solution containing 28.0 g of the strong electrolyte calcium chloride, $CaCl_2$, dissolved in 295 g of water?
2. What is the boiling point of a solution composed of 850 g of ethylene glycol, $C_2H_6O_2$, mixed with 1100 g of water?