

## ChemQuest 40

# Colligative Properties

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Hour: \_\_\_\_\_

**Introduction Question:** Melting Ice

1. In colder climates during the winter, people put salt on the roads and walkways to melt ice. Why do people do this? Why does salt melt the ice?

**Information:** Dissociation and Total Molality of Particles

When you dissolve a solute in a solvent, the resulting solution has slightly different properties than the original solvent. For example, salt water has a different freezing point and boiling point than pure water. The salt interferes with water's ability to freeze and boil. A solution, therefore, will always have a *higher* boiling point and a *lower* freezing point than the pure solvent.

When ionic compounds dissolve, they dissociate. When an ionic compound dissociates that means that it breaks up into ions. For example, salt (sodium chloride) breaks up into sodium ions and chloride ions. This process is represented in the following balanced equation:



Note for the above equation that  $\text{Cl}^-$  does not need to be written as  $\text{Cl}_2$  because  $\text{Cl}^-$  is a chloride ion and not a lone chlorine atom.

Since calcium nitrate is an ionic compound it also dissociates as shown below:



Covalent molecules do not dissociate. Although they may dissolve, they do not break up into ions.

**Critical Thinking Questions**

2. Write the balanced equation for the dissociation of magnesium chloride.
3. Write the balanced equation for the dissociation of ammonium sulfate.

4. Consider calcium nitrate. Each calcium nitrate breaks up into one calcium ion and two nitrate ions according to the balanced equation given in the information section. If you take one mole of calcium nitrate and put it in water, it will dissociate.
- How many moles of calcium ions and how many moles of nitrate ions will there be in the solution?
  - What is the total number of moles of all ions in the solution?
5. A solution is made so that it is 2.5 M  $\text{Ca}(\text{NO}_3)_2$ . Therefore the concentration of  $\text{Ca}^{2+}$  is 2.5 M and the concentration of  $\text{NO}_3^-$  is 5.0 M. The total concentration of all particles is 7.5 M. Explain.
6. A solution is made so that the concentration is 3.0 m  $\text{MgCl}_2$ . What is the molality of  $\text{Mg}^{2+}$  and  $\text{Cl}^-$  ions? What is the total molality of all particles in the solution?

$\text{Mg}^{2+}$  \_\_\_\_\_  $\text{Cl}^-$  \_\_\_\_\_ Total molality of all particles: \_\_\_\_\_

7. A solution is prepared by dissolving 45.7 g of sodium carbonate in 200 g of water.
- What is the molality of the sodium carbonate?
  - What is the total molality of all particles in the solution?
8. Consider sugar ( $\text{C}_6\text{H}_{12}\text{O}_6$ ), a covalent molecule. If a solution is made so that the concentration is 3.5 m in sugar, then what is the total molality of particles?

### **Information:** Total Molality of Particles and Changes in Boiling/Freezing Points

You may be wondering how all of this ties together. We have seen that adding a solute changes the boiling and freezing points of solvents. The amount of the change depends on how much solute is added. Equations relating the change in boiling or freezing point and the molality is shown below:

$$\Delta T_{\text{bp}} = (m_{\text{T}})(K_{\text{bp}}) \text{ for boiling point} \qquad \Delta T_{\text{fp}} = (m_{\text{T}})(K_{\text{fp}}) \text{ for freezing point}$$

Note:  $m_{\text{T}}$  is the total molality of particles.  $K_{\text{bp}}$  and  $K_{\text{fp}}$  are constants called the molal boiling point elevation constant and the molal freezing point depression constant respectively.  $K_{\text{bp}}$  for water is  $0.515 \text{ }^\circ\text{C}/\text{m}$  and  $K_{\text{fp}}$  for water is  $1.853 \text{ }^\circ\text{C}/\text{m}$ .

## **Critical Thinking Questions**

9. What is the freezing point of a 2.5 m solution of salt water. Hints: first find  $\Delta T_{fp}$  and then subtract the change from the original freezing point ( $0^{\circ}\text{C}$  for water). Also, remember  $m_T$  is not 2.5 m in this problem.
10. Find the boiling point of a 3.7 m solution of calcium chloride.
11. What is the freezing point of a sugar solution in which the concentration of sugar is 2.25m? Note: sugar is covalent so it dissolves but it does not dissociate.

## **Information: Raoult's Law**

A solution will almost always have a lower vapor pressure than the pure solvent. For example, salt water will have a lower vapor pressure than pure water. The vapor pressure of a solution ( $P_{\text{solution}}$ ) is related to the vapor pressure of the pure solvent ( $P_{\text{solvent}}$ ) by the mole fraction of the solvent ( $X_{\text{solvent}}$ ) in an equation known as Raoult's Law:

$$P_{\text{solution}} = (X_{\text{solvent}})(P_{\text{solvent}})$$

## **Critical Thinking Questions**

12. The vapor pressure of water at  $20^{\circ}\text{C}$  is 2.3 kPa. What is the vapor pressure of a solution formed by dissolving 21.5g of LiCl in 84.3g of  $\text{H}_2\text{O}$  at  $20^{\circ}\text{C}$ ?