Name ______________________ Date ____________ Class ____________

Freezing Point Depression with Antifreeze

Lab 45
APPLICATION

Introduction

Have you ever wondered how antifreeze lowers the freezing point of water in the cooling systems of automobiles? In the latter part of the nineteenth century the French chemist François Raoult noted that the vapor pressure of a solvent was lowered by the addition of a solute (Raoult's Law), and that the freezing points of solutions also were lowered.

Eventually, the following mathematical expression that related freezing point depression and molality (moles of solute per kilogram of solvent) was developed.

$$\Delta T = K_f m$$

In this equation, ΔT is freezing point depression, K_f is the molal freezing point constant for the solvent, and m is the molality of the particles in solution.

As you can see from the equation, the lowering of the freezing point depends on the concentration of dissolved particles present. In the case of a nonelectrolyte, the molality of the nonelectrolyte and the molality of particles in solution are the same (a 1:1 ratio). For electrolytes, the molality of particles is equal to the molality of the electrolyte times the number of ions in the chemical formula of the compound.

Automobile manufacturers make use of the principle of freezing point depression to protect engines from freezing in cold weather. Antifreeze, a nonelectrolyte, is added to the water-filled radiator that cools the engine. Under most conditions the presence of the antifreeze molecules in the water is sufficient to keep the system from freezing.

In this investigation, you will determine the freezing point depression of antifreeze solutions by cooling them in an ice-salt bath. You will also use this information to find the molar mass of ethylene glycol.

Pre-Lab Discussion

Read the entire laboratory investigation and the relevant pages of your textbook. Then answer the questions that follow.

1. What is the mathematical relationship between freezing point depression and molality?
2. What is a colligative property?

Name ______________________________

3. What precautions should be taken with antifreeze when performing this investigation?

4. What is the reference point for freezing point depression in this investigation?

5. Why is Calculation Step 5 necessary?

6. Write the mathematical expression for molality.

7. Write the mathematical expression that relates the mass, number of moles, and molar mass of a substance.

8. Using these two expressions, derive an equation for calculating the molar mass of a sample if you know its mass and the freezing point depression it causes for water.

Problem

How can you find the freezing point depression of water solutions of antifreeze and the molar mass of ethylene glycol?

Materials

chemical splash goggles
laboratory apron
beaker, 600-mL
300 mL crushed ice
sodium chloride (NaCl)
stirring rod
thermometer
paper towels or aluminum foil
3 large test tubes
distilled water
2 beakers, 250-mL
marking pen
laboratory balance
40 mL antifreeze
graduated cylinder, 10- or 25-mL
dropper
graduated cylinder, 100-mL

Name ______________________________

Lab 45
APPLICATION

Safety

Wear your goggles and lab apron at all times during the investigation. Commercial antifreeze is primarily ethylene glycol, which is highly toxic. The ice used in the investigation could become contaminated with antifreeze by accident. Do not eat the ice. Note the caution alert symbols here and with certain steps of the Procedure. Refer to page *xi* for the specific precautions associated with each symbol.

Procedure

1. Put on your goggles and lab apron. Half fill a 600-mL beaker with ice and cover it with about 20 grams of sodium chloride ($NaCl$). Stir this ice-salt mixture with a stirring rod until it reaches a constant temperature at or below $-10°C$. Cover the outside of the beaker with paper toweling or aluminum foil with the reflective side in.
2. Half fill a test tube with distilled water and place it in the ice bath. Rinse the stirring rod and use it to stir the water gently until ice crystals first appear. Use a thermometer to measure the freezing point and record it in the Data Table. **CAUTION:** *Thermometers are fragile. Do not use the thermometer as a stirring rod.*

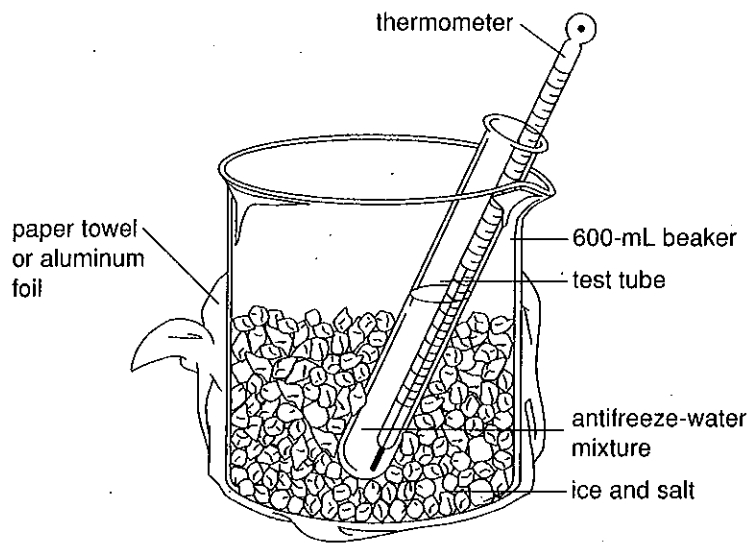

Figure 44–1

3. Find the mass of a 250-mL beaker. Leaving the beaker on the balance, set the balance for an additional 10.00 grams. Add antifreeze to the beaker carefully from a 10- or 25-mL graduated cylinder. **CAUTION:** *Antifreeze is toxic. Do not drink it. If you spill any, rinse it off with plenty of water and tell your teacher.* When the balance is close to equalization, add the final antifreeze with a dropper. Now add 100 mL of distilled water to the beaker and stir thoroughly with the stirring rod. In a similar fashion, prepare a second solution using 20.00 grams of antifreeze. Label the beakers *Solution 1* and *Solution 2*.

Name ________________________________

4. Half fill a test tube with Solution 1 and place it in the ice/salt bath. Rinse the stirring rod and use it to stir the solution gently until the temperature is 0°C. Add a small chip of ice to the solution. (This will eliminate the possibility of supercooling.) Continue to stir until the first appearance of slush ice. Measure the temperature and record it in the Data Table.
5. Repeat Step 4 with Solution 2.
6. Dispose of the antifreeze solution in the container provided by your teacher. Clean up your work area and wash your hands before leaving the laboratory.

Observations

DATA TABLE

freezing point of distilled water (T_{H_2O})	
freezing point of Solution 1 (T_1)	
freezing point of Solution 2 (T_2)	

Calculations (based on sample data)

1. Determine the freezing point depression of Solution 1.

2. Determine the freezing point depression of Solution 2.

3. Determine the molality (m) of Solution 1. (K_f = $-1.86°C{\cdot}kg/mol$ for water)

4. Determine the molality (m) of Solution 2.

5. To find the molar mass of antifreeze, you first need to calculate the number of grams of antifreeze per 1000 grams of solvent for the solutions.

   Solution 1 1000 g H_2O ×

   Solution 2 1000 g H_2O ×

6. Find the molar mass of antifreeze. (Note: Review your answers to Pre-Lab Questions 6–8.)

   Solution 1

   Solution 2

Name ____

Lab 45
APPLICATION

Critical Thinking: Analysis and Conclusions

1. Permanent antifreeze is almost 100% ethylene glycol (1, 2 ethanediol, $C_2H_4(OH)_2$). Calculate its molar mass. *(Applying concepts)*
2. Calculate the percent error in both trials. *(Interpreting data)*

   Solution 1

   Solution 2

3. What do you think are the major sources of error in this investigation? How might some of them be reduced? *(Interpreting data)*

Critical Thinking: Applications

1. Could freezing point depression be used for substances not soluble in water? *(Making predictions)*
2. What effect on the freezing point depression of water would a 1 *m* solution of the ionic substance $(NH_4)_3PO_4$ have? *(Making predictions)*
3. What assumption is made about the density of distilled water in this investigation? *(Making inferences)*
4. Would this method of molar mass determination be practical for other substances soluble in water? *(Applying concepts)*