CHM 115 Lab 8

Properties of Solutions: Freezing Point Depression

The purpose of this experiment is to demonstrate one of the colligative properties of solutions - freezing point depression. The magnitude of the freezing point lowering depends on the nature of the solvent and the concentration of solute species. By measuring the amount the freezing point is lowered by the addition of a known amount of solute to a given amount of a particular solvent, it is possible to determine the molecular weight of the solute. The lowering of the freezing point, ΔT_f is proportional to the concentration of the solution when the concentration is expressed in molality.

$$\Delta T_f = -iK_f \cdot m$$

i, the number of particles, K_f, the molal freezing point depression constant for the solvent, has the units kg solvent ×°C /mol solute, and molality, m, is mol solute/ kg solvent.

The lowering of the freezing point is the difference in the freezing point of the pure solvent and that of the solution. (Recall that at the freezing point temperature both solid and liquid are in equilibrium.)

In this experiment paradichlorobenzene is used as the solvent because of its convenient melting point and its large K_f value. Since paradichlorobenzene is particularly susceptible to super-cooling, its freezing point is best determined by the use of cooling curves. During super-cooling the liquid will cool below the equilibrium freezing point before any solid forms, and then the temperature will increase back toward the equilibrium temperature. Examples of typical cooling curves for a pure solvent and a solution are given at the end of the procedure.

Procedure:

Work with a partner to collect data (Steps 1-6); the analysis of the data is to be done individually. Each pair of students should obtain from the stockroom: large test tube fitted with a stopper, digital thermometer and stirrer, and a numbered unknown.

You will collect (a) two sets of time-temperature data for the determination of the freezing point of the solvent, (b) two sets for the determination of the freezing point of a dilute solution of the unknown, and (c) two sets for a more concentrated solution. Using these six sets of data you will plot six cooling curves and from the freezing points determined, calculate the molecular weight of the unknown.

1) Set up your burner and tripod, and begin heating water in a 400mL beaker. On the top-loading balance weigh about 25 grams of paradichlorobenzene to the nearest 0.01 g and put it in the large test tube. Clamp the test tube so that it is immersed in the hot water bath. After the solid has melted, install the stopper with thermometer and stirrer. Carefully raise the test tube from the water bath and dry with a paper towel. With constant gentle mixing, watch the temperature. When the temperature reaches about 60 °C, begin recording the temperature every 30 seconds. Continue the time-temperature readings until the system becomes difficult to mix. (Suggestion: **record time and temperature in a tabular form**)

Caution: Stir gently and be careful not to break the stir rod.

2) Using the hot water bath, reheat the solid until it has melted. Then repeat step 1, collecting a second set of time-temperature data (from about 60 °C to the point where it is mostly solid).

3) Weigh about 3 grams of the unknown, to the nearest 0.01g.

4) Remelt the solid in the water bath. Add the weighed sample and dissolve the solid by mixing thoroughly. When the temperature drops to about 60 °C, start collecting time-temperature data as was done with the pure solvent. As before, reheat the system and collect a second set of data for Solution 1.

5) Weigh a second approximately 3 gram sample of the unknown, to the nearest 0.01g. Remelt the solution and add the second weighed sample to produce Solution 2. **Note: the mass of solute is the sum of the two samples**. Collect two sets of time-temperature data for this solution.

6) To clean up after completing the experiment: Carry your test tube with stopper, thermometer, and stirrer to the hood; heat the contents until it has melted; use the stirrer to get as much solid as possible into the liquid; remove the stopper and parts, and quickly pour the melt into the labeled container. Use a minimum amount of acetone from the wash bottle to dissolve any remaining solid and pour this into the container.

For the report form:

For each trial, plot time on the x-axis and temperature on the y-axis. Draw a straight line to represent the cooling before the liquid begins to solidify and a second straight line through the points during solidification. Extend both lines so that they cross. This intersection is the best estimate of the freezing point of the liquid. Plot all six sets of data (individual instructors may want all 6 sets on one graph, offset as show below. Listen to the specific directions given to your class).

Calculate the molecular weight of the unknown. Make two calculations, one from data for Solution 1 and one from data for Solution 2. For each solution use the average of the two freezing points (from the two cooling curves) to determine the freezing point depression for the solution. The value of K_f for paradichlorobenzene is 7.1 kg solvent °C / mol of solute.