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**Exp. 14 Molar Mass of a Solid**

**Purpose:**

* To observe and measure the effect of a solute on the freezing point of a solvent
* To determine the molar mass (molecular weight) of a nonvolatile, nonelectrolyte solute

**Materials and Reactions (if any):**

* 250-mL, 400-mL and 600-mL beaker
* paper towel
* 300 mL of an ice–water
* digital or glass thermometer
* 200-mm test tube
* 12 mL of cyclohexane
* Unknown solid solute

**Procedure:**

* **Safety precautions**
  + If the thermometer is a glass thermometer, handle the thermometer carefully. If the thermometer is accidentally broken, notify your instructor immediately.
  + Cyclohexane is flammable—keep away from flames; cyclohexane is a mucous irritant—do not inhale.

1. Freezing Point of Cyclohexane (Solvent)
   1. Prepare the ice–water bath. Assemble the apparatus. A 400-mL beaker is placed inside a 600-mL beaker, the latter being an outside insulating beaker. You may want to place a paper towel between the beakers to further insulate the ice–water bath. Place about 300 mL of an ice–water slurry into the 400-mL beaker. Obtain a digital or glass thermometer, mount it with a thermometer clamp to the ring stand, and position the thermometer in the test tube.
   2. Prepare the cyclohexane. Determine the mass (±0.01 g) of a clean, dry 200-mm test tube in a 250-mL beaker. Add approximately 12 mL of cyclohexane to the test tube. Place the test tube containing the cyclohexane into the ice–water bath. Secure the test tube with a utility clamp. Insert the thermometer probe and a wire stirrer into the test tube. Secure the thermometer so that the thermometer bulb or thermal sensor is completely submerged into the cyclohexane.
   3. Record data for the freezing point of cyclohexane. While stirring with the wire stirrer, record the temperature at timed intervals (15 or 30 seconds). The temperature remains virtually constant at the freezing point until the solidification is complete. Continue collecting data until the temperature begins to drop again.
   4. Plot the data. On linear graph paper or by using appropriate software, plot the temperature (ºC, vertical axis) versus time (sec, horizontal axis) to obtain the cooling curve for cyclohexane.
2. Freezing Point of Cyclohexane plus Unknown Solute
   1. Measure the mass of solvent and solid solute. Dry the outside of the test tube containing the cyclohexane and measure its mass in the same 250-mL beaker. On weighing paper, tare the mass of 0.1–0.3 g (±0.001g) of unknown solid solute and record. Quantitatively transfer the solute to the cyclohexane in the 200-mm test tube.
   2. Record data for the freezing point of solution. Determine the freezing point of this solution in the same way as that of the solvent. Record the time and temperature data. When the solution nears the freezing point of the pure cyclohexane, record the temperature at more frequent time intervals. A “break” in the curve occurs as the freezing begins, although it may not be as sharp as that for the pure cyclohexane.
   3. Plot the data on the same graph. Plot the temperature versus time data on the same graph as those for the pure cyclohexane. Draw straight lines through the data points above and below the freezing point; the intersection of the two straight lines is the freezing point of the solution.
   4. Repeat with additional solute. Remove the test tube and solution from the ice–water bath. Add an additional 0.1–0.3 g (±0.001g) of unknown solid solute using the same procedure as in Part B.1. Repeat the freezing-point determination and again plot the temperature versus time data on the same graph. The total mass of solute in solution is the sum from the first and second trials.
   5. Again. Repeat with additional solute. Repeat Part B.4 with an additional 0.1–0.2 g (±0.001g) of unknown solid solute, using the same procedure as in Part B.1. Repeat the freezing-point determination and again plot the temperature versus time data on the same graph (Parts B.2–4). The total mass of solute in solution is the sum for the masses added in Parts B.1, B.4 and B.5. You now should have four plots on the same graph.
3. Calculations
   1. From the plotted data, determine ∆Tf for Trial 1, Trial 2, and Trial 3. Refer to the plotted cooling curves (see Figure 14.3).
   2. From kf, the mass (in kg) of the cyclohexane, and the measured ∆Tf, calculate the moles of solute for each trial. See equations 14.1 and 14.3.
   3. Determine the molar mass of the solute for each trial.
   4. What is the average molar mass of your unknown solute?
   5. Calculate the standard deviation and the relative standard deviation (%RSD) for the molar mass of the solute.

**Calculations (if any):**