**What's That Salt?**



 

Your dad has been trying to reduce his expenses and would like to save some money on driveway salt to melt unsafe ice. He would like to buy the cheaper generic brand that claims to work as well as his favorite brand. He knows enough about chemistry to know that if the two brands have the same ingredients in the same amounts they should work the same. There is only one problem, neither bags lists the ingredients.

Doing a little research online, he has narrowed the possible choices for ingredients down to 4 different salts. Knowing that you are currently studying general chemistry, he has asked for your help figuring out whether or not the two brands have the same salts in them. Before you can help your dad you realize you need to figure out the answer to two questions:

1. What is the chemical basis for using salt to melt ice?
2. Can you use this this chemical property to design an experiment that would answer your dad's question?

**Background**

The amount of solute dissolved in a liquid affects the liquid’s boiling point, freezing point, and vapor pressure. These three properties are collectively known as colligative properties, and depend on only the *number* of solute particles present in a given amount of solvent, not on the *identity* of particles dissolved. When a solid is dissolved in a liquid, the freezing point of that liquid is depressed. It is possible to calculate the extent of the depression using *m*, the molality of the solution, and kf, a constant characteristic of the solvent used, as shown in the following expression:

  (1)

Molality, *m*, is a measure of solute concentration, and is defined by the following expression:

  (2)

Typically when the identity of the solute and the *k*f of the solvent are known, the formula can be used to predict how much the freezing point will be depressed. If however, you don’t know what the solute is but you know how much was added to a known amount of solvent you can use the relationship between ΔTf and molality to determine the molar mass of the unknown substance. Since molar mass is calculated from the molecular formula, knowing the molar mass can help you identify the unknown.

In this experiment, you will be asked to determine the molar mass of an unknown solute. The solvent, *tert*-butyl alcohol (TBA), has a convenient melting point (23-26 °C)1, and a moderately large value for *k*f, 8.09 kg ⋅ °C/mol. The freezing points will be obtained by observing the rate at which the liquid cools over time and graphing temperature vs. time.

**Procedure**

Part A: Determination of Freezing Point of *tert*-butyl alcohol (TBA)

1. Carefully insert thermometer into one hole of the rubber stopper, unless this has already been done for you. Handle the thermometer with care when fitting it into the stopper or adjusting its position, since the thermometer is both fragile and expensive. If necessary, use glycerin.
2. Place a test tube into the 250 mL beaker and tare. Add approximately 25.0 g *tert*-butyl alcohol (TBA) in the test tube and measure the mass. If the liquid solidifies, warm the TBA by immersing the test tube in a beaker of warm tap water.
3. Stopper the test tube, making sure the stirring rod can move freely in the second hole of the rubber stopper. The readings on the thermometer should be visible from 35 °C to 10 °C when the tip is in the TBA.
4. Fill the 600 mL beaker with ice water (5-15 °C). The final water level should be within 1 cm of the top of the beaker.
5. Fill the 250 mL beaker with 200 mL hot tap water (approximately 37 °C ).
6. Warm the test tube by immersing it in the hot tap water, making certain the TBA in the test tube is completely submerged in the hot water. Stir occasionally with the glass rod until the temperature of the TBA reads approximately 37 °C.
7. Place the 600 mL beaker of ice water on the base of a ring stand. Clamp the test tube into place so that the test tube is immersed as far as possible into the ice water.
8. Stir *continuously* with the glass rod. The stirring keeps the temperature constant throughout the liquid and prevents supercooling (the cooling of a liquid below its freezing point without it becoming a solid).
9. When the temperature reaches **35 ºC**, begin recording the temperature every 30 seconds for 8 minutes. The temperature will start to become level near the freezing point.
10. Warm the test tube using hot water, until it is possible to safely remove the thermometer and stirring rod. **Save the TBA for Part B**.

Part B: Determination of the Molar Mass of an Unknown Compound

1. Measure approximately 1.0 g of unknown solid and record the mass. Transfer the sample into the test tube of **TBA saved from Part A** and dissolve completely. Using this solution (solution 1) repeat steps 3-9 from Part A
2. After completion of the trial, warm the test tube with hot water until the solution has melted completely and save for the next step.
3. Measure an additional 1.0 g of unknown solid and record its mass. Transfer the second sample of unknown into the test tube from the previous step and dissolve completely. Repeat steps 3-9 from Part A using this solution (solution 2) with the following change. For this trial, begin recording data when the temperature reaches **33 ºC**.

**Data Collection**

Copy tables 1 and 2 into your notebook. Be sure that the entire table is on one page.

**Table 1.** Masses used for freezing point determinations.

|  |  |
| --- | --- |
| *tert*-butyl alcohol (g) |  |
| unknown *(your letter)* solute in solution 1 (g) |  |
| additional unknown *(your letter)* solute added to solution 2 (g) |  |

**Table 2.** Freezing point of pure *tert*-butyl alcohol, solutions 1 and 2.

|  |  |  |  |
| --- | --- | --- | --- |
| time (s) | temperature of*tert*-butyl alcohol (°C) | temperature of solution 1 (°C) | temperature of solution 2 (°C) |
| 0 |  |  |  |
| 30 |  |  |  |
| 60 |  |  |  |
| 90 |  |  |  |
| 120 |  |  |  |
| 150 |  |  |  |
| 180 |  |  |  |
| 210 |  |  |  |
| 240 |  |  |  |
| 270 |  |  |  |
| 300 |  |  |  |
| 330 |  |  |  |
| 360 |  |  |  |
| 390 |  |  |  |
| 420 |  |  |  |
| 450 |  |  |  |
| 480 |  |  |  |

**Analysis**

As a liquid cools, its temperature decreases over time. When the temperature versus time data is plotted on a graph, two distinct regions become apparent. The first region has a steeper slope and represents when the solution is completely liquid. The second region has either a very shallow slope or a slope of zero, and represents when solid and liquid co-exist. The freezing point of the solution is found at the point of intersection of those two lines, as shown in Figure 1.

In Excel, plot the temperature vs. time readings for pure *tert*-butyl alcohol and for solutions 1 and 2 **on separate graphs**. Using a ruler, draw two straight lines through the points on each graph as illustrated in Figure 1. Determine the freezing point of each solution as illustrated from the intersection of these lines. The freezing point depression, ΔTf, for solutions 1 and 2 is the difference between the freezing point for pure *tert*-butyl alcohol and that of each respective solution.

**Reference**

1. Sigma Aldrich Catalog. www.sigmaaldrich.com. (accessed 2/20/2008).

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