# Molar Mass Determination by Freezing Point Depression in *t*-Butyl Alcohol

# Introduction

Pure molecular substances can exist in three physical states: solid, liquid, or gas. The extent to which the individual molecules are free to move independently of each other is different in each of these states. This freedom results from the extent to which one molecule has influence on, or is influenced by, other molecules in its immediate vicinity. The physical state of a substance depends upon two factors:

1. Intermolecular interactions resulting from hydrogen-bonding, dipole-dipole interactions, and/or dispersion forces characteristic of the particular substance.
2. The amount of kinetic energy possessed by the molecules of the substance, which depends on temperature.

In the solid phase, the molecules of a substance have insufficient kinetic energy to overcome intermolecular attractions. Therefore, the substance has rigid structure. When we heat a solid substance, the kinetic energy of the molecules increases. They begin to move with respect to one another. As we continue to heat the substance, the molecular motion becomes sufficient to cause the outer parts of the rigid structure to being to break down, and we obtain a mixture of the solid and liquid. We call the breakdown process **melting** and the temperature at which the transition occurs the **melting point**. Application of additional heat converts the entire sample from solid to liquid. In the liquid phase, intermolecular interactions are weaker than in the solid phase.

We can reverse the melting process at any point simply by removing heat from the substance. For example, as a pure liquid cools, the molecules lose kinetic energy. At some temperature they have insufficient energy to overcome intermolecular forces, and the solid phase begins to form. We call the chance from liquid to solid **freezing** and the temperature at which the transition occurs the **freezing point**. The melting and freezing points of a substance should theoretically be the same. Because freezing and melting depend only on temperature and the particular intermolecular interactions characteristic of a substance, the freezing (or melting) point is a **physical constant** of the substance.

When we dissolve a nonvolatile **solute** in a liquid, we obtain a **solution**. The liquid in which the solution dissolves is the **solvent**. The presence of a solute affects the freezing behavior of the solvent. In particular, the freezing temperature will be lower for the solution than for the pure solvent. The extent of the freezing point depression depends on the concentration of the solution, and what the solvent is:

# Materials and Methods

Sample text

# Procedure

**Part I. Determining the freezing temperature of *t-*butyl alcohol**

Caution: Avoid inhaling fumes of *t-*butyl alcohol or ingesting it. USE ONLY AN ABSOLUTELY DRY TEST TUBE FOR THIS EXPERIMENT.

Weigh a large test tube in a 250-mL Erlenmeyer flask. Record the mass. Measure 25 mL of *t-*butyl alcohol in a graduated cylinder and transfer the alcohol to the test tube. Measure the mass of the alcohol, test tube, and flask. Record the mass.

Assemble the apparatus shown below. Place the thermometer so that the end of the thermometer bulb is at the midpoint of the t-butyl alcohol and so the thermometer does not touch the side of the test tube. Adjust the stirrer so that it can be moved from the bottom of the test tube to almost the top of the liquid.



Fill the 600-mL beaker two-thirds full of cold tap water. If the water is greater than , add a small amount of ice to cool it below . Measure the temperature of the water and record it.

Immerse the test tube assembly in the cold water. Position the test tube assembly in the ice-water so that the test tube is in the center of the beaker. Make certain the level of the alcohol in the test tube is 5 mm below the water level of the beaker.

Stir the alcohol continuously and steadily during the determination. Record time and temperature data every 15 s, beginning immediately after you place the test tube in the ice-water bath. End the determination 3 minutes after the alcohol has become slushy.

Remove the assembly from the water bath. Use your hands to warm the test tube and melt the alcohol. Raise the alcohol temperature do .

Repeat the determination using the same sample of *t-*butyl alchol. Save the alcohol for Part II.

**Part II. Determining the molar mass of an unknown**

Add several pieces of ice to your ice-water bath.

Weigh approximately 2.0 g of an unknown using weighing paper. Record the exact mass of unknown used. Carefully transfer the solid unknown to the test tube containing your *t-*butyl alcohol from Part I.

Carefully stir the *t-*butyl alcohol and unknown until the unknown has **COMPLETELY DISSOLVED** and the solution appears to be homogeneous.

Check the temperature of your ice-water bath. If the temperature is not between and add several pieces of ice to the bath.

Immerse the assembly in the ice-water bath. Position the test tube as you did in Part I. Be sure the level of the solution in the test tube is 5 mm below the surface of the water in the beaker. Constantly stir the unknown solution and the ice-water bath. Record the time-temperature data every 15 s, beginning immediately after you placed the test tube in the ice-water bath. End the determination 3 minutes after the solution has become slushy.

Remove the assembly from the ice-water bath. Use your hands to warm the test tube and melt the solution. Raise the temperature to . Do another determination, using the same solution.

Discard the unknown solution in a waste container.

# Data and Results

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# Conclusions

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# References

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