# Molar Mass by Freezing Point Depression

## Introduction

A pure liquid has a vapor pressure, and a solution made with the liquid as the solvent also has a vapor pressure. However, because of the additional intermolecular forces acting between the solute and solvent, the vapor pressure at a given temperature is less than that of the purse substance. Since boiling and freezing are functions of vapor pressure, it can be shown that the freezing point of a solution is lower than that of the pure solvent and the boiling point is higher than the pure solvent.

The size of the change in freezing point, ΔTf, is a function of the concentration of the solution. The relationship is

The term ΔTf refers to the difference in freezing points of the solvent and solution, k is the freezing point depression constant of the solvent, and m is the molality of the solution:

Since molar mass is defined as the mass of the substance per mole, the change in freezing point can be used to find the molality, which in turn can be used to find the equivalent moles of solute. If the mass of the solute is also measured, then mass divided by moles will be the experimental molar mass of the substance.

## Materials and Methods

t-butyl alcohol

unknown solute

50-mL beaker

Thermometer or temperature probe

Graduated cylinder

Ice bath

## Procedure

1. Record the mass of a clean and dry 50-mL beaker to the closest 0.001 g on the Report Sheet.
2. Measure 25 mL of *t-*butyl alcohol in a graduated cylinder and transfer it to the beaker. Record the total mass of the Report Sheet and calculate the mass of the alcohol.
3. Create an ice bath in a 400-mL beaker. Use a temperature probe to stir the liquid in the beaker and record the temperature when the alcohol *just begins* to freeze on the Report Sheet. If the t-butyl alcohol is pure, then the temperature should stay constant during the full freezing process.
4. Record the mass of approximately 2.0 g of an unknown to the closest 0.001 gram and add the solid to the t-butyl alcohol. Warm the solution, as needed to completely dissolve the unknown.
5. Place the beaker back in the cold-water bath and record the temperature when solid material *first* appears. Warming and cooling the solution near the freezing point several times may be helpful to identify an accurate freezing point.
6. Discard the unknown solution in the labeled waste container and complete the calculations of molar mass on the Report Sheet.

## Data and Results

1. Calculate the mass of the solvent, in kg, by subtracting the mass of the beaker from the mass of the beaker and solvent.
2. Calculate the molality of the solution from the change in freezing point and the freezing point depression constant for t-butyl alcohol, 8.37 C/m.
3. Calculate the moles of solute from the molality of the solution and the mass of solvent.
4. Calculate the molar mass of the solvent by dividing the mass of solute by the moles of solute.