

Using Freezing-Point Depression to Find Molecular Weight

When a solute is dissolved in a solvent, the freezing temperature is lowered in proportion to the number of moles of solute added. This property, known as freezing-point depression, is a *colligative property*; that is, it depends on the ratio of solute and solvent particles, not on the nature of the substance itself. The equation that shows this relationship is:

$$\Delta T = K_{fp} \cdot m \cdot i$$

where “ ΔT ” is the freezing point depression, “ K_{fp} ” is the freezing point depression constant for a particular solvent, “ i ” is the van’t Hoff factor (non-electrolytes = 1), and “ m ” is the molality of the solution (in mol solute/kg solvent).

In this experiment, you will first find the freezing temperature of the pure solvent, BHT (2, 6-di-*t*-butyl-4-methylphenol, $((\text{CH}_3)_3\text{C})_2\text{CH}_3\text{C}_6\text{H}_2\text{OH}$, F.W. 220.36. You will then add a measured mass of unknown molecular solute, to a known mass of BHT, and determine the lowering of the freezing temperature of the solution. By measuring the freezing point depression, ΔT , and the mass of the unknown solute, you find the molecular weight of the unknown solute, in g/mol.

The K_{fp} of BHT is known to be $9.30 \text{ C}^0/\text{m}$

BHT is a food preservative (antioxidant) used in both human and animal foods that contain a large amount of fat or oil. It is also used to preserve rubber, plastics, and soaps, and functions as an antiskinning agent in paints and inks.

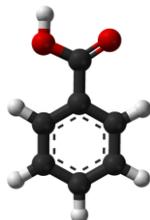
OBJECTIVES

In this experiment, you will

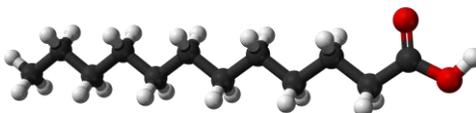
- Determine the freezing temperature of pure BHT.
- Determine the freezing temperature of a solution of BHT and an unknown solute.
- Examine the freezing curves for each.
- Calculate the experimental molecular weight of the unknown.
- Identify the possible identity of the unknown substance.

Possible Identities of the Unknown Molecular Solute

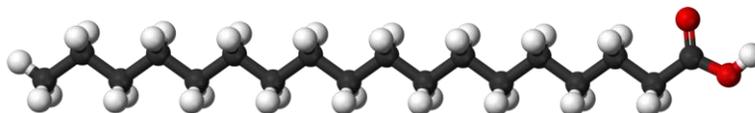
Benzoic acid (C_6H_5COOH) is also a food preservative used in fatty foods and fruit juices. It is also used as a pharmaceutical aid as an antifungal agent which is used for the treatment of fungal skin diseases such as tinea, ringworm, and athlete's foot.. It has been mixed with salicylic acid and used as a topical antifungal. It also has found use in a wide variety of chemistry laboratory uses such as a standard in calorimetric analysis, a mordant in dyes, and the manufacture of benzoates and benzoly compounds. Benzoic acid occurs naturally as do its esters in many plant and animal species. Appreciable amounts have been found in most berries (around 0.05%) especially ripe cranberries and bilberries.

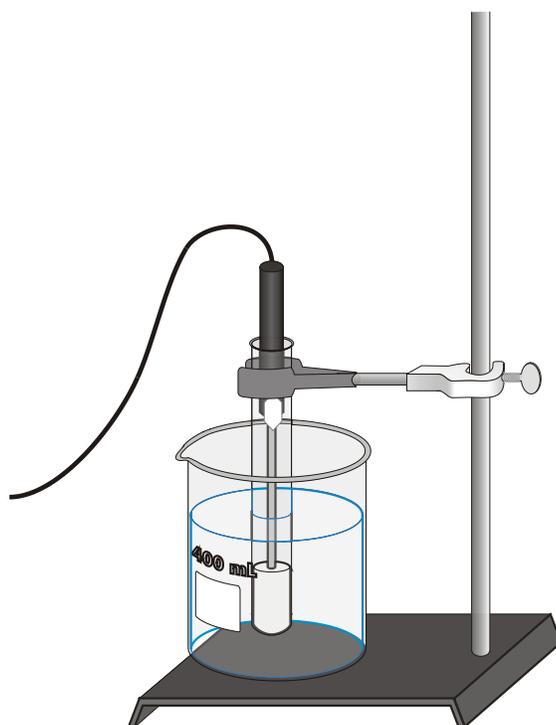


Lauric acid ($CH_3(CH_2)_{10}COOH$) is a component of triglycerides, and comprises about half of the fatty acid content in coconut oil, laurel oil, and palm kernel oil (not to be confused with palm oil). Otherwise, it is relatively uncommon. It is also found in human breast milk (6.2% of total fat), cow's milk (2.9% of total fat), and goat's milk (3.1% of total fat). Like many other fatty acids, lauric acid is inexpensive, has a long shelf-life, and is non-toxic and safe to handle. It is mainly used for the production of soaps and cosmetics. In the laboratory, lauric acid is often used to investigate the molar mass of an unknown substance via the freezing-point depression. Lauric acid increases total serum cholesterol the most of any fatty acid. But most of the increase is attributable to an increase in high-density lipoprotein (HDL) (the "good" blood cholesterol). As a result, lauric acid has been characterized as having "a more favorable effect on total HDL cholesterol than any other fatty acid, either saturated or unsaturated".



Stearic acid ($CH_3(CH_2)_{16}COOH$). Its name comes from the Greek word "stéar", which means tallow. The salts and esters of stearic acid are called stearates. Stearic acid is one of the most common saturated fatty acids found in nature following palmitic acid. As a component (esterified) of fats, stearic acid occurs in many animal and vegetable fats and oils, but it is more abundant in animal fat (up to 30%) than vegetable fat (typically <5%). Stearic acid is mainly used in the production of detergents, soaps, and cosmetics such as shampoos and shaving cream products. Soaps are not made directly from stearic acid, but indirectly by saponification of triglycerides consisting of stearic acid esters. Esters of stearic acid with ethylene glycol, glycol stearate, and glycol distearate are used to produce a pearly effect in shampoos, soaps, and other cosmetic products.





PROCEDURE

1. Obtain and wear goggles.
2. Connect TWO Temperature Probes to the computer interface. Prepare the computer for data collection by opening the file “15 Freezing Pt Depression” from the *Chemistry with Vernier* folder.
3. Place about 300 mL of hot water in to a 400 mL beaker. Place the beaker on a hot plate and plug it in and/or turn it on.
4. Obtain 3 weighing dishes. Label them 1, 2, and 3 by writing on them with a pen, pencil, or marker.
 - Put 2 scoops of BHT into weighing dish 1
 - Put 1 scoop of BHT into weighing dish 2
 - Put 1 scoop of Unknown into weighing dish 3

Determine the mass of each dish with its contents.

Obtain 2 test tubes from your teacher.

Write a “P” on one for “PURE” and an “M” on the other for “MIXTURE”.

Pour dish 1 into the test tube labeled “P” and pour dishes 2 and 3 into the test tube labeled “M”.

BE CAREFUL TO NOT SPILL ANY OF THE SOLIDS. Place the empty dishes back onto the balance to obtain their empty masses.

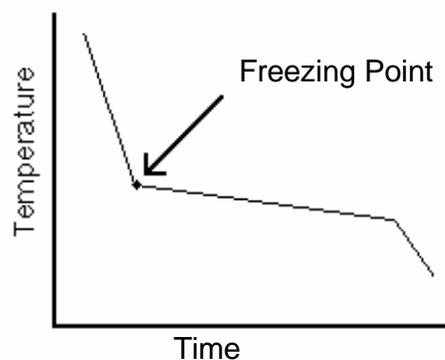
Experiment 15

- Attach a utility clamp to each test tube and carefully place the two test tubes into the boiling water and melt the contents.

WHILE STILL IN THE HOT WATER BATH, insert a Temperature Probe into the hot melted contents of each test tube. It takes about 30 seconds for the probe to warm up to the temperature of its surroundings and give correct temperature readings. After this time, fasten the utility clamps to the support rod so the test tubes are suspended above the table top. Then click  to begin data collection.

- With a very slight up and down motion of the Temperature Probes, *continuously* agitate the hot liquid during the cooling. Hold the top of the probe and *not* its wire.
- Continue with the experiment until data collection has stopped after 10 minutes. Use the hot water bath provided by your teacher to melt the probe out of the solid BHT. *Do not* attempt to pull the probe out—this might damage it. Carefully wipe any excess BHT liquid from the probe with a paper towel or tissue. Return the test tube containing BHT to the place directed by your teacher.
- To determine the freezing temperature of pure BHT, you need to determine the mean (or average) temperature in the portion of graph with nearly constant temperature. In your “graph options”, display only the temperature curve for the pure BHT on the graph. Move the mouse pointer to the beginning of the graph’s flat part. Press the mouse button and hold it down as you drag across the flat part of the curve, selecting only the points in the plateau. Click on the Statistics button, . The mean temperature value for the selected data is listed in the statistics box on the graph. Record this value as the freezing temperature of BHT. Close the statistics box.
- Next, display only the MIXTURE cooling curve. Click on the

Examine button, . To determine the freezing point of the mixed solution, you need to determine the temperature at which the mixture initially started to freeze. Unlike pure BHT, cooling a mixture results in a gradual linear decrease in temperature during the time period when freezing takes place. As you move the mouse cursor across the graph, the temperature (y) and time (x) data points are displayed in the examine box on the graph. Locate the initial freezing temperature of the solution, as shown here. Record the freezing point in your data table.



- To print a graph of temperature vs. time showing **both data runs**:
 - Click on the vertical-axis label of the graph. To display both temperature runs, click More, and check the Run 1 and Latest Temperature boxes. Click .
 - Label both curves by choosing Text Annotation from the Insert menu, and typing “BHT” and “MIXTURE” in the edit box. Then drag each box to a position on or near its respective curve.
 - Print the graph.

REPORT PAGE

PROCESSING THE DATA

NAME _____ DATE _____

1. Determine the difference in freezing temperatures, Δt , between the pure BHT (t_1) and the mixture (t_2).
Use the formula, $\Delta t = t_1 - t_2$.
2. Using $K_f = 9.3^\circ\text{C}\cdot\text{kg/mol}$ for BHT, calculate the molecular mass of the unknown solute. Consult your class notes for the proper equation to use for this calculation.
3. Determine the identity of your unknown and CLEARLY STATE IT BELOW.
7. Attach your graph to this page

DATA AND CALCULATIONS

Mass of BHT + Dish 1	g
Mass of BHT + Dish 2	g
Mass of Unknown + Dish 3	g
Mass of Empty Dish 1	g
Mass of Empty Dish 2	g
Mass of Empty Dish 3	g
Mass of BHT in Mixture	g
Mass of unknown in Mixture	g
Freezing temperature of pure BHT	°C
Freezing point of BHT in mixture	°C