EFFECT OF FREEZING POINT DEPRESSION ON MIXED SACCHARIDES-PROTEIN SOLUTIONS

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INTRODUCTION

The melting/freezing point of a substance is the temperature at which it changes between the solid and liquid states. For most substances, this is a reversible process (Note: some substances decompose on melting). For water, this change occurs at 0°C. Other substances have different melting/freezing points.

When a substance (usually a liquid) has a second substance dissolved in it, the freezing point of the mixture is lower than that of the pure substance. The amount that the freezing point is change is determined by the number of particles (mole fraction) of solute dissolved in the liquid. This principle is applied when rock salt is used to melt the ice on roads and sidewalks in the winter. The resulting salt solution freezes at a lower temperature than pure water and thus will not form ice if the temperature drops below freezing.

When a liquid freezes, the particles take on an orderly arrangement as a solid called a crystal lattice. The presence of a solute disrupts the process because the solvent molecules tend to surround the solute and the resulting crystal lattice of the mixture is not as orderly as the pure solvent alone. As a result, more energy must be removed from a solution for it to become a solid and the freezing point is depressed. The freezing point depression is the difference between the freezing point of the pure solvent and the solution.

Materials Needed

Apparatus:

NOTE: This procedure uses special equipment and glassware. Do not use any apparatus from your laboratory locker unless specifically instructed to do so.

400 mL beaker or paper or plastic cup, 12 to 15 ounces
150°C thermometer
10-mL graduated cylinder or measuring spoons
250-mL graduated cylinder or measuring cups
balance or measuring cups
aluminum foil
Zip-Loc bags (quart size and gallon size)
plastic spoons

Chemicals:

sucrose crystals
lactose-protein solution
4-hydroxy-3-methoxybenzaldehyde
sodium chloride
(optional: theobromine powder)

Safety

Safety glasses or goggles must be worn in the laboratory at all times.

If this experiment is performed in a chemistry laboratory, all work surfaces must be cleaned and free from laboratory chemicals. After cleaning work surfaces, it is advised to cover all work areas with aluminum foil or a food-grade paper covering.

All glassware and apparatus used in this experiment must be clean and free from laboratory chemicals. Special apparatus, reserved specifically for this experiment will be provided.

CAUTION: Materials in this experiment will be cold. Handle cold materials carefully to avoid frostbite.

Disposal

Generally, all waste materials in this experiment can be disposed in the trash or poured down the drain with running water. All disposal must conform to local regulations.

Procedure

Work in groups of 2 persons.

Using soap and water, wash all the glassware that is to be used in this experiment. Also, wipe down the benchtop where you are working with a soap solution, wipe clean, and dry with paper towels. This cleaning is extremely important as dirt will interfere with the results of this experiment.

It is recommended that the benchtop be covered with aluminum foil.

Obtain two quart size Ziploc bags.

Into each bag place the following materials:

125 mL (1/2 cup) lactose-protein solution
16 g (4 tsp) sucrose crystals
1.5 mL (1/4 tsp) of 4-hydroxy-3-methoxybenzaldehyde

If desired, 6.0 g (1 Tbs.) of theobromine powder can be added to each bag.

Squeeze as much air as possible out of the Ziploc bags, without spilling any of the contents, and seal the bags (i.e., "zip" them).

Obtain two gallon size Ziploc bags. Fill a 400-mL beaker (1 2/3 cups) with ice and add that amount of ice to each bag.

Measure 110 g (1/3 cup) of sodium chloride and add that to ONE of the bags containing the ice. Label the bag that contains the sodium chloride.

Place one of the small Ziploc bags containing the lactose-protein solution in each of the large bags - containing the ice or ice-sodium chloride mixture. Squeeze out some of the air in each bag and seal them.

Knead both bags for 7-10 minutes. Record any changes that occur in each bag during this time.

After kneading the bags, open the outer bags and measure the temperature of the ice and ice-sodium chloride mixtures. Record the temperatures.

Remove the inner bags from the larger bags and inspect their contents. Wipe off any liquid from the outside of the small bag using a paper towel. You may taste the contents of the smaller, inner Ziploc bag using a clean plastic spoon.

Clean up the materials. Rinse any solutions down the drain. Throw used bags, spoons, and plastic cups in the trash.

Questions

1. What happened to the materials inside the inner bags during this experiment? Why?

2. What is the function of the sodium chloride mixed with the ice?

3. How much was the freezing point depressed?

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TEACHER NOTES

This experiment is the preparation of ice cream (actually ice milk).

The ingredients are:

lactose-protein solution is milk (either whole milk or low-fat milk)
sucrose crystals is table sugar
4-hydroxy-3-methoxybenzaldehyde is vanilla extract

theobromine powder is cocoa powder (Hershey's, Nestles, etc…)

It is suggested that all the ingredients be kept in their original containers with labels listing the "chemical" names, lactose-protein solution, sucrose, 4-hydroxy-3-methoxybenzaldehyde, and theobromine. Place across the front of the container. Do not, however, obliterate the actual name of the substance as it is desired to have the student make a connection between the "chemical" name and the common name of the substance.

Only one of the mixtures will freeze, the one in the ice-salt mixture. The temperature of the ice-salt mixture in that bag is usually about –5 to –10ºC (23º to 14ºF) but it may be as low as -17ºC (0ºF). (NOTE: When the Fahrenheit temperature scale was developed, it was thought that the lowest temperature that could be obtained was that of a mixture of ice and salt. That was designated as 0ºF.) If the students would like to freeze the second bag of ice cream mix (the one in the ice only mixture), they can place it in a bag of ice and salt.

Ice cream is a frozen foam made from a mixture of milk or cream with sugar, an emulsifier such as egg yolk or a vegetable gum such as guar gum, and flavoring. When ice cream is made, it consists of up to one-third air, incorporated into the mixture by beaters in the ice cream machines while the mixture is freezing. Without the air, the ice cream would be a solid block of ice. In this experiment, the kneading of the bags incorporates air into the mixture.

In this particular recipe, the standard vanilla ice cream will be fairly sweet. If a student prefers to make chocolate ice cream by the addition of cocoa, the recipe did not compensate with extra sugar to counteract the bitterness of the cocoa powder. Thus, the chocolate ice cream will have more of a bittersweet chocolate flavor.

This activity can be used for a class party or birthday with each student making their own ice cream. Substitute other flavorings such as strawberry flavor, mint flavor, etc…. Add a tablespoon or two of chopped fresh fruit such as strawberries or peaches. Make different mixtures by adding nuts, chocolate chips, M&M's, crushed candy bars, marshmallows, or other confections.

Another variation of this experiment, that is an excellent demonstration/activity for a class or a conference is liquid nitrogen ice cream.