Super-cooling Water and Snap Freezing

Abstract

Can water remain liquid below its normal freezing point? If it does, that water is *supercool*(-ed). This project shows you a method for supercooling water. You can test water from different sources to see whether or not it can be supercooled.

Objective

The goal of this project is to investigate *supercooling* of water. Supercooling is when water remains liquid below it's normal freezing point of 0°C. Does prior heating of the water make it easier to supercool water without freezing?

Introduction

At what temperature does water freeze? That's easy: 0°C (32°F). Did you know that water can sometimes be cooled *below* the freezing point and still remain liquid? This is called *supercooling*.

All matter is made of atoms. The atoms are constantly moving: whizzing around in gases, tumbling around in liquids—even in solid material the atoms are vibrating. The temperature of a piece of matter is a measure of the average motion of the molecules that make up that piece of matter. The lower the temperature, the less molecular motion there is. As the temperature increases, the energy of the molecules increase. When the temperature increases sufficiently, matter can change from solid to liquid or from liquid to gas or from gas to plasma. Each of these states of matter (solid, liquid, gas, plasma) is called a *phase* of matter. It takes energy to change from one phase to another, energy which is used to alter the chemical bonds between the molecules.

When water freezes, the molecules of liquid become locked in a crystalline array. The molecules in the crystal have less energy than molecules in liquid water. They move less. So in order to go from liquid water to solid ice, water must lose energy.

When water is cooled to its freezing point, ice crystals begin to form and grow in the water. It is thought that these initial crystals often form around impurities in the water. If you start with a sample of pure water, and cool it slowly, you can produce supercooled liquid water. When ice is added to supercooled water, it acts to catalyze the crystallization of the liquid. The water instantly freezes solid. This is sometimes called "snap freezing."

In this project you will use salt and ice to make a "bath" that is below the normal freezing point of water. The dissolved salt causes the bath to have a temperature below the normal freezing point of water. This pheonomenon is called *freezing point depression*. You can use your salt/ice bath to cool various water samples to investigate which samples can be supercooled, and which samples freeze at the normal freezing point. It's fun to see water suddenly freeze solid. Can you figure out conditions for reliably producing supercooled water?

Terms, Concepts, and Questions to Start Background Research

- change of phase,
- freezing,
- heat of fusion,
- heat of vaporization,
- supercooling,
- freezing point depression.

Questions

- How does adding salt to ice make it colder?

Materials and Equipment

To do this experiment you will need the following materials and equipment:

- large bowl,
- ice,
- salt,
- distilled water,
- thermometer (good range would be -10°C to 110°C)
- transparent plastic cups (tip: a tall, narrow shape works best),
- piece of cardboard (e.g., empty cereal box),
- scissors.

Experimental Procedure

Procedure for Super-cooling Water

1. Cut a circle from the cereal box to use as a cover for the plastic cup.
2. Pour a small sample of distilled water into a clean plastic cup and place the cup in the center of the bowl.
3. Cover the cup, then add ice cubes to the bowl, so that the ice is above the level of water in the cup. Be careful not to get any ice inside the cup.
4. Sprinkle two tablespoons of salt over the ice cubes. Be careful not to get any salt inside the cup.
5. Uncover the cup and put the thermometer inside.
6. Monitor the temperature of the water. Over the next 10–20 minutes or so, you should see the temperature slowly decrease. Keep track of the time and temperature in your lab notebook.
7. When the temperature of the water reaches –1 to –3 degrees C or 30 to 28 degrees F, carefully remove the cup from the ice bath.
8. Repeat the procedure, testing different types of water to see whether it can be supercooled before freezing. For each type of water, run at least three trials (more is better). Here are some ideas for types of water to test:
    a. bottled distilled water,
    b. plain tap water,
    c. any of the above that have been boiled and then allowed to cool to room temperature.

Snap Freezing Super-cooled Water

- Drop a small piece of ice into the cup of supercooled water. What happens?

- How does the temperature change when the water freezes? Can you explain why?

- Tip: to avoid breakage, allow the frozen water to thaw before attempting to remove the thermometer from the cup.