The Heat-Retaining Properties of Water and Soil

Topic

Water has the ability to retain heat longer than soil.

Introduction

Have you ever stepped outside on a cold morning to find the ground beneath you frozen solid? Even so, the water in a nearby large body of water may still be in the liquid state. How can soil freeze while water in a big lake or in the ocean remains in the liquid state? The answer is found in water's unusual chemical properties.

Water is a *polar molecule*, so it has a slight positive charge on one end and a slight negative charge on the other end (see Figure 1). Like tiny magnets, the negative end of one water molecule is attracted to the positive end of another. These attractive forces between water molecules are called *hydrogen bonds*. In this experiment, you will see how the hydrogen bonds in water affect its ability to hold heat.

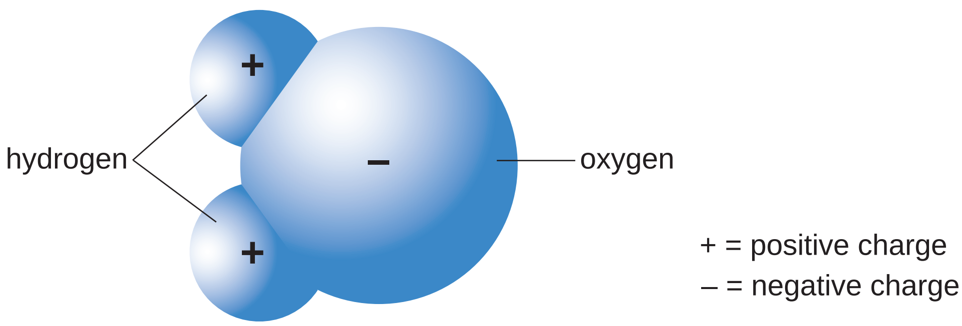
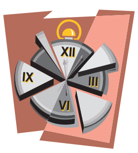


Figure 1
Water molecule



Time Required

55 minutes

Materials

- 2 large Styrofoam™ cups
- 2 thermometers
- heat lamp
- graduated cylinder
- soil (about 1 cup)
- water (about 1 cup)
- electronic scale or triple-beam balance
- clock or timer
- marking pen or labels
- science notebook

Safety Note **Take special care when working with the heat lamp. Please review and follow the safety guidelines.**

Procedure

1. Half fill a Styrofoam™ cup with soil.
2. Determine the mass of the soil. To do so:
   a. Place the empty cup on the electronic scale and find its mass. Record the mass in your science notebook.
   b. Remove the empty cup and replace it with the cup of soil.
   c. Determine the mass of the cup of soil and record it in your science notebook.
   d. Subtract the mass of the empty cup from the mass of the cup and soil to find the mass of the soil.
3. Place an equal mass of water in the empty cup. (Remember that 1 milliliter [ml] of water has a mass of 1 gram [g].)
4. Gently insert a thermometer into each cup.
5. Place both cups under the heat lamp and leave them there for 30 minutes (min).

6. While the cups of water and soil are under the heat lamp, copy the data table in your science notebook and answer Analysis questions 1 and 2.
7. After 30 min, turn off the heat lamp. Read the temperature on each thermometer. On your data table in the row titled "Starting temperature," record the temperatures of the soil and water.
8. Every 2 min for the next 20 min, check the temperature in each cup. Record the temperatures on the data table in the appropriate row.
9. Answer Analysis questions 3 through 9.

Data Table

	Cup of soil	Cup of water
Starting temperature		
2 minutes		
4 minutes		
6 minutes		
8 minutes		
10 minutes		
12 minutes		
14 minutes		
16 minutes		
18 minutes		
20 minutes		

Analysis

1. Write a hypothesis that explains why the first freeze of winter may cause ice crystals to form in the soil, but does not cause water in a large lake to freeze. Explain the logic behind your hypothesis.

2. Why do you think it is important to use the same mass of soil and water in this experiment?
3. In your experiment, which showed the greatest change in temperature, the soil or water?
4. According to your experimental results, which substance can hold heat the longest, soil or water?
5. How did your experimental findings compare to your hypothesis?
6. Chicago, Illinois, is on the banks of Lake Michigan. In Chicago, the temperature may be 14 degrees Fahrenheit [°F] (– 10 degrees Celsius [°C]) for a week, yet Lake Michigan does not freeze. Using your experimental results, explain why.
7. Based on your experimental results, how do you think the difference in the heat-retaining abilities of soil and water might affect climate along the coast?

What's Going On?

Water can retain heat longer than most other substances. The ability of a substance to hold heat without becoming very warm itself is referred to as *heat capacity*. Heat energy is measured in calories. Heat energy of 1 calorie is required to raise the temperature of 1 g of water 1°C. In comparison, only one-eighth as much energy is needed to raise the temperature of 1 g of iron by the same amount. Water has any unusually high heat capacity due to the presence of hydrogen bonds between adjacent water molecules.

For most substances, heat directly affects molecules, causing them to vibrate faster and move apart. Water reacts differently to heat. When water is heated, the initial input of energy breaks apart the hydrogen bonds between water molecules. During this period, water maintains its temperature. After all the hydrogen bonds are broken, individual water molecules begin to vibrate and separate, and the temperature increases. Therefore, it takes more heat to raise the temperature of 1 g of water than it does for any other substance. The reverse is also true; as water cools, the water molecules first form hydrogen bonds with each other, maintaining their temperature as they do so. Eventually, cooling slows the motion of the water molecules and the temperature of a water sample drops. The presence of hydrogen bonds causes water to heat slower, and cool slower, than other substances.

Connections

The ability of water to hold heat affects climate. Because water holds heat better than soil, ocean temperatures show little variation at night, remaining relatively warm. On nearby land masses, temperatures may drop significantly. When ocean-warmed air rises at night, cool air from the land flows in to replace it, causing wind to blow offshore. During the day, the land warms up faster than the ocean, reversing the situation. Warm air over land rises and cooler ocean air flows in to replace it. For this reason, onshore winds blow during the day.

Water's heat-retaining abilities mean that cities located along coastlines experience less-drastic changes in temperature from day to night than inland regions. In addition, the climates of these regions are milder, showing fewer temperature extremes. For example, the average high temperature in coastal San Francisco during the summer is 68°F (20°C); 20 miles (32.19 kilometers [km]) inland, the average high is 87°F (31°C). Although climate is a complex phenomenon, part of this difference is due to the fact that the ocean does not heat as quickly in the summer as the nearby land. As a result, areas near the ocean are cooler than areas that are surrounded by land.

Want to Know More?

See Our Findings.

OUR FINDINGS

THE HEAT-RETAINING PROPERTIES OF WATER AND SOIL

Idea for class discussion: Show students a beaker of soil and a beaker of water. Explain that the class is going to do an experiment to find out which one retains heat longer. Ask students to make predictions about what their experiment will show. Revisit predictions after the activity.

Analysis

1. Answers will vary.
2. In a controlled experiment, all variables must be the same except the one being tested.
3. soil
4. water
5. Answers will vary.
6. Lake Michigan is able to retain heat longer than the air and soil around it.
7. The heat-retaining ability of water moderates temperatures around the coast.

SAFETY PRECAUTIONS

Review Before Starting Any Experment

Each experiment includes special safety precautions that are relevant to that particular project. These do not include all the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read and remain mindful of the General Safety Precautions that follow. Experimental science can be dangerous, and good laboratory procedure always includes following basic safety rules. Things can happen very quickly while you are performing an experiment. Materials can spill, break, or even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following the basic safety guidelines during the entire experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. For one reason, we want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical.

Read the safety precautions here and at the beginning of each experiment before performing each lab activity. It is difficult to remember a long set of general rules. By rereading these general precautions every time you set up an experiment, you will be reminding yourself that lab safety is critically important. In addition, use your good judgment and pay close attention when performing potentially dangerous procedures. Just because the book does not say “Be careful with hot liquids” or “Don’t cut yourself with a knife” does not mean that you can be careless when boiling water or using a knife to punch holes in plastic bottles. Notes in the text are special precautions to which you must pay special attention.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking an unnecessary risk can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the individual experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone. When you are working off-site, keep in groups with a minimum of three students per groups, and follow school rules and state legal requirements for the number of supervisors required. Ask an adult supervisor with basic training in first aid to carry a small first-aid kit. Make sure everyone knows where this person will be during the experiment.

PREPARING

- Clear all surfaces before beginning experiments.
- Read the instructions before you start.
- Know the hazards of the experiments and anticipate dangers.

PROTECTING YOURSELF

- Follow the directions step by step.
- Do only one experiment at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure there is adequate ventilation.
- Do not horseplay.
- Keep floor and workspace neat, clean, and dry.
- Clean up spills immediately.
- If glassware breaks, do not clean it up; ask for teacher assistance.
- Tie back long hair.
- Never eat, drink, or smoke in the laboratory or workspace.
- Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult.

USING EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives or other sharp-pointed instruments with care.

- Pull plugs, not cords, when removing electrical plugs.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.
- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use alcohol-filled thermometers, not mercury-filled thermometers.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read labels carefully.
- Avoid chemical contact with skin and eyes (wear safety glasses, lab apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING SUBSTANCES

- Wear safety glasses, apron, and gloves when boiling water.
- Keep your face away from test tubes and beakers.
- Use test tubes, beakers, and other glassware made of Pyrex™ glass.
- Never leave apparatus unattended.
- Use safety tongs and heat-resistant gloves.
- If your laboratory does not have heat-proof workbenches, put your Bunsen burner on a heat-proof mat before lighting it.
- Take care when lighting your Bunsen burner; light it with the airhole closed, and use a Bunsen burner lighter in preference to wooden matches.

- Turn off hot plates, Bunsen burners, and gas when you are done.
- Keep flammable substances away from flames and other sources of heat.
- Have a fire extinguisher on hand.

FINISHING UP

- Thoroughly clean your work area and any glassware used.
- Wash your hands.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Do not dispose of materials in the sink unless instructed to do so.
- Clean up all residues and put them in proper containers for disposal.
- Dispose of all chemicals according to all local, state, and federal laws.

BE SAFETY CONSCIOUS AT ALL TIMES!