Density

Strand	Matter	
Topic	Investigating density	
Primary SOL	6.5	The student will investigate and understand the unique properties and characteristics of water and its roles in the natural and human-made environment. Key concepts include b) the properties of water in all three phases.
Related SOL	6.1	The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which g) data are collected, recorded, analyzed, and reported using metric measurements and tools; h) data are analyzed and communicated through graphical representation.

Background Information

Properties of water include its high surface tension and the large range of temperature (0–100°C) in which it can be found in the liquid state. Another remarkable property is that unlike other substances, it *expands* when it freezes; thus, ice is less dense than water.

A water molecule has two hydrogen atoms and one oxygen atom (H_2O). Two molecules of water can form a *hydrogen bond* between them. The oxygen atom of one water molecule has two lone pairs of electrons, each of which can form a hydrogen bond with the hydrogen atoms on another water molecule. This can repeat so that every water molecule is H-bonded with up to four other molecules. Liquid water's high boiling point is due to the high number of hydrogen bonds each molecule can have relative to its low molecular mass.

As water freezes into ice, the molecules become frozen in place and begin to arrange themselves in a rigid lattice-like structure. The structure that forms in the solid ice crystal actually has large holes in it. Ice forms rigid clusters of hexagonal patterns, with a hydrogen atom from one molecule forming a hydrogen bond with an oxygen atom of another molecule. This leaves plenty of space between the oxygen atoms of one water molecule to those of the next. Therefore, in a given volume of ice, there are fewer water molecules than in the same volume of liquid water. In other words, ice is less dense than liquid water and, therefore, will float on the surface of the liquid.

Liquid water is not so orderly, and water molecules are able to pack together more tightly. Water is most dense at 4°C.

The distance between the molecules depends on the temperature, but the molecules never move so close as to touch each other because there is repulsion on the negative oxygen atoms similar to the repulsion between two magnets.

Materials

- Two beakers
- Water
- Hot plate

- Food coloring
- Eyedropper
- Graduated cylinders
- Triple beam balances
- Freezer
- Plastic wrap
- Rubber bands
- Copies of the attached handout

Vocabulary

atoms, hydrogen, hydrogen bond, liquid, molecular bonding, molecule, oxygen, solid

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Introduction

1. As a demonstration, place 200 ml of chilled water in a beaker or container, and allow it to settle for one minute.
2. Add five drops of food coloring to 30 ml of hot water. The temperature difference between the cold and hot water should be as great as possible. Allow the coloring to spread throughout the water. Ask, "What makes the coloring spread?"
3. Using an eyedropper, slowly place several milliliters of the hot colored water onto the bottom of the beaker of cold water. Try not to disturb this hot colored water as you withdraw the eyedropper.
4. Instruct students to observe the beaker. Ask the following questions as they are making their observations.

   "How does the hot water behave in the cold water?"

   "Why does the hot water float to the top?"

   "What does it mean that hot water is less dense than cold water?"
5. After several minutes, have students make observations again. Ask the following questions.

   "What change do you notice?"

   "What are the hot molecules doing now?"

   "How does the density of liquid water relate to temperature?

Procedure

1. Ask students the following questions, giving them time to ponder each one:
   - What is density?
   - What do we have to know in order to calculate the density of an object?
   - Which is denser, liquid water or solid water?
   - How can you show which is denser?
   - How can we determine the density of liquid water and solid water?
   - How can we measure the mass and volume of ice and be sure that we do not lose any molecules during the change to liquid?

2. Pass out copies of the attached How Dense Can It Be? lab sheet, and have students read the steps and determine the independent and dependent variables. Also, have them write the purpose and form a hypothesis.
3. Have students conduct the experiment, as directed on the lab sheet.

Observations and Conclusions

1. Have students complete the lab sheet and Reflection Questions on their own. Allow them to check their answers with a neighbor before having a class discussion of the results. Then ask the following questions:
   - Which is denser, liquid water or solid water?
   - What happens to the molecules of water when it freezes?
   - What would happen if ice didn't float?
   - Why is this property of water essential for life?
2. Organize students into groups of three each in order to model water molecules. Have each group stand together and decide who will be the two hydrogen atoms and who will be the oxygen atom. Have all the groups demonstrate liquid water molecules by moving close together in no particular pattern, but making sure each group stays together. Then, tell them to demonstrate ice by moving into a pattern with the hydrogen atoms loosely bonding with an oxygen atom from another molecule.

Assessment

- **Questions**
  - What atoms make up a liquid water molecule? How are they arranged?
  - Why is ice less dense than liquid water?
- **Journal/Writing Prompts**
  - Describe the difference in arrangement between molecules of water in the solid state and molecules of water in the liquid state.
  - Explain how to calculate the density of water in the solid and liquid states.
- **Other**
  - As an Exit Ticket, have students draw a picture of water molecules in liquid and solid states, and have them explain why ice is less dense than liquid water.
  - Have students write limerick poems about the arrangement of atoms in liquid and solid states.

Extensions and Connections (for all students)

- Have students design and conduct an experiment that uses the same steps but a different liquid. Discuss the results.
- Have students design an experiment using a marble and a variety of liquids to determine their relative densities (least to greatest).

Strategies for Differentiation

- Use building blocks to demonstrate molecular configurations that occur in more and less dense materials.
- Use a physical model to represent crystal structure.
- Provide hands-on materials such as Unifix cubes to model 3-D components of a graph.
- Have students work in pairs or assigned groups to answer the Reflection Questions.

- Have students share in small groups.
- Have students review vocabulary by writing each word on an index card along with its definition, a sentence that uses it, and a picture of the concept.
- Have students include vocabulary in a science glossary.
- Have students use graphic organizers to compare and contrast the density and/or structure of liquid and solid water at various temperatures.

How Dense Can It Be?

Name: _____ **Date:** _____ **Class:** _____

Purpose

Hypothesis

Materials

Celsius thermometer, small graduated cylinder, triple-beam balance, water, freezer, plastic wrap, rubber band

Procedure

Independent Variable:

Dependent Variable:

Constants:

Steps

1. Measure the mass of the graduated cylinder, and record. _____
2. Pour 15 ml of room-temperature water into the graduated cylinder. Measure the mass of the graduated cylinder and water, and record. _____
3. Subtract the mass of the graduated cylinder from the combined mass to determine the mass of the water only. Record. _____
4. Place plastic wrap over the top of the graduated cylinder, and secure with a rubber band. Place the graduated cylinder in the freezer overnight.
5. Calculate the density of water by dividing the mass of the water by the volume of the water. Record. _____
6. On the next day, measure the volume and mass of the ice. Subtract the mass of the graduated cylinder, and record. _____
7. Calculate the density of the ice, and record. _____

Qualitative Observations

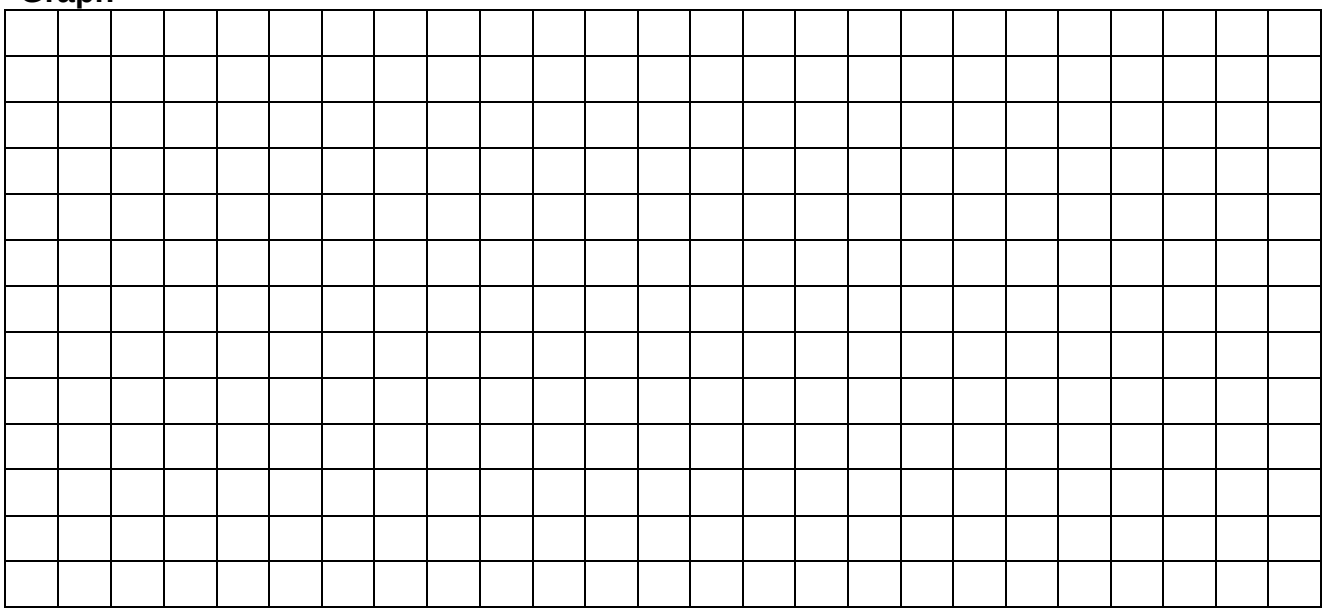
Water:

Ice:

Data Table

Independent Variable (IV)	Dependent Variable (DV)		
	Mass of water (g)	Volume of water (ml)	Density (mass/volume) (g/ml)
Water			
Ice			

Graph



Reflection Questions

1. Did the volume of the water change when it froze? _____ If so, how did it change?

2. Calculate how much the volume changed as a percentage of the original volume. Do this by dividing the frozen volume by the liquid volume and then multiplying by 100. The frozen volume should be greater than 100% of the liquid volume. What is the percent? _____
3. Since you know that ice is less dense than water, what do you think happens to the water molecules when water freezes?

4. If ice were denser than water, what would happen when ice forms on the surface of a lake? _____ What would happen to water creatures in this scenario?

5. Try this experiment with other liquids, such as syrup, vegetable oil, soda, salt water, and melted butter. Do you think you'll get the same results? _____ Why, or why not?

Conclusions

1. What was your hypothesis?
2. Do the results of your experiment support your hypothesis? _____
3. Was your hypothesis correct or incorrect? _____
4. What happened in the investigation?

5. Use the average data and your answers to the Reflection Questions to summarize the results. Explain why the results happened as they did, and include all discoveries you made. Make an inference based on what you now know.