

## Chapter 3, Lesson 6: Temperature Affects Density

### **Key Concepts**

- Heating a substance causes molecules to speed up and spread slightly further apart, occupying a larger volume that results in a decrease in density.
- Cooling a substance causes molecules to slow down and get slightly closer together, occupying a smaller volume that results in an increase in density.
- Hot water is less dense and will float on room temperature water.
- Cold water is more dense and will sink in room temperature water.

### **Summary**

Students place hot and cold colored water into room temperature water. They observe that the hot water floats on the room temperature water and the cold water sinks. Students will combine the concepts of temperature, molecular motion, and density to learn that hot water is less dense than room temperature water and that cold water is more dense.

### **Objective**

Students will be able to explain, on the molecular level, how heating and cooling affect the density of water.

### **Evaluation**

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

### **Safety**

Make sure you and your students wear properly fitting goggles. Use caution when handling hot water.

### **About this Lesson**

In this lesson, you can help students connect some of the concepts about density to ideas from Chapter 1. In Chapter 1, students saw that heat increases molecular motion. This increased motion competes with the attractions between molecules, causing the molecules to move a little further apart. They also saw that as a substance is cooled, molecules slow down, and their attractions bring them closer together. These ideas can also be applied to the concept of density.

### **Materials for Each Group**

- Cold water (colored blue) in foam cup
- Hot water (colored yellow) in foam cup
- Room temperature water in clear plastic cup (colorless)
- 2 droppers

### **Materials for the Demonstration**

- Hot water (colored yellow)
- Cold water (colored blue)
- 2 identical clear baby food jars
- Water-resistant card (from a deck of cards or laminated index card)
- Paper towels

## **ENGAGE**

### **1. Do a demonstration to show that hot water floats on cold water.**

Tell students that in Chapter 3, they have seen that different substances have different densities. In this activity, they will see that the *same* substance can have *different* densities at different temperatures.

Tell students that you are going to try to place one jar filled with hot colored water upside down over another jar with cold colored water.

Ask students to make a prediction:

- **Do you think the hot and cold water will mix or stay separate?**

Either follow the procedure below or project the video for students. If you decide to do the demonstration, you may want to watch the video first in order to see how to set the jars up.

**Project the video *Hot Water on Cold Water*.**

[www.acs.org/middleschoolchemistry/simulations/chapter3/lesson6.html](http://www.acs.org/middleschoolchemistry/simulations/chapter3/lesson6.html)

### **Materials**

- Hot water (about 50 °C, colored yellow)
- Cold water (about 5 °C, colored blue)
- 2 identical clear baby food jars
- Water-resistant card (from a deck of cards or laminated index card)
- Paper towels

### **Procedure**

#### ***Hot water on top***

1. Completely fill a baby food jar with hot tap water and add 2 drops of yellow food coloring.

2. Completely fill another baby food jar with very cold water and add 2 drops of blue food coloring. Stir the water in both jars so that the coloring is well-mixed in both. Place the cold water jar on a paper towel.
3. Hold a water-resistant card over the top of the hot water jar.
4. While holding the card against the jar opening, carefully turn the jar upside down.
5. With the card still in place, position the jar of hot water directly over the jar of cold water so that the tops line up exactly.
6. Slowly and carefully remove the card so that the hot water jar sits directly on top of the cold water jar.



### **Expected results**

Although removing the card may result in a little mixing or spilling, the hot yellow water will remain in the top jar and the cold blue water will remain in the bottom jar.

Ask students:

- **Why do you think the hot water stayed on top of the cold water?**  
Students should realize that there is a density difference between hot and cold water. Hot water is less dense so it floats on the denser cold water.

Ask students to make a prediction:

- **What might happen if you placed the cold blue water on top of the hot yellow water and then removed the card?**

### ***Cold water on top***

7. Use the same procedure as above, but place the jar of cold water, upside down over the jar of hot water.

### **Expected results**

The cold blue water will immediately fall into the hot yellow water causing mixing. The water will quickly become green throughout.

Ask students:

- **Why do you think the hot and cold water mixed when the cold water was placed on top?**

When the cold water is placed on top, the colors mix because the cold water is more dense and sinks in the hot water.

**Give each student an activity sheet.**

Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms and Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually depending on your instructions. Look at the teacher version of the activity sheet to find the questions and answers.

## EXPLORE

2. Have students try adding cold and hot water to room temperature water.

### Question to investigate

Is there a density difference between hot and cold water?

### Materials for each group

- Cold water (colored blue) in foam cup
- Hot water (colored yellow) in foam cup
- Room temperature water in clear plastic cup (colorless)
- 2 droppers

### Teacher preparation

- Add ice to water to make very cold water. Half-fill one foam cup with cold water (no ice cubes) and another with hot water for each group.
- Add 2 drops of yellow food coloring to the hot water and 2 drops of blue food coloring to the cold water.
- Fill a clear plastic cup about  $\frac{2}{3}$  of the way with room temperature water.
- Distribute the set of 3 cups to each group.

### Procedure

1. Fill one dropper with blue cold water. Poke the end of the dropper about halfway into the colorless room temperature water.
2. While observing from the side, very gently squeeze the dropper so that the cold water slowly flows into the room temperature water.



3. Fill another dropper with yellow hot water. Poke the end of the dropper about halfway into the room temperature water.
4. While observing from the side, very gently squeeze the dropper so that the hot water slowly flows into the room temperature water.
5. Record your observations on the activity sheet.

### **Expected results**

The cold blue water will flow down and collect at the bottom of the room temperature water. The hot yellow water will rise and collect at the surface.

### **3. Discuss student observations.**

Ask students:

*About cold water*

- **What did you notice when you placed the cold blue water in room temperature water?**  
The cold water sank in the room temperature water.
- **Is cold water more, less, or the same density as room temperature water?**  
Cold water is more dense than room temperature water.

*About hot water*

- **What did you notice when you placed the hot yellow water in room temperature water?**  
The hot water floated to the surface in the room temperature water.
- **Is hot water more, less, or the same density as room temperature water?**  
Hot water is less dense than room temperature water.

## **EXPLAIN**

4. **Explain the difference in density between hot and cold water on the molecular level.**

**Project the animation *Cold and Hot Water*.**

[www.acs.org/middleschoolchemistry/simulations/chapter3/lesson6.html](http://www.acs.org/middleschoolchemistry/simulations/chapter3/lesson6.html)

### **Cold water**

Point out that the molecules of cold water move slower and are a little closer together than the hot or room temperature water. Also point out that when the water is cooled, the water level falls slightly in the graduated cylinder.

Ask students:

- **In the animation, you saw that as water is cooled the water level goes down. Cold water has a smaller volume, but the mass stays the same. What does this tell you about the density of cold water?**

Students should understand that when the molecules come together as the water is cooled, the volume decreases. But the mass of the water does not change. Students should realize that decreasing the volume without increasing the mass is going to increase the density.

- **How does this help explain why cold water sinks in room temperature water?**

The more dense cold water sinks in the room temperature water.

### **Hot water**

Point out that the molecules in the hot water are moving faster and are a little farther apart than the molecules in room temperature water. Make sure students notice that when the water is heated, the water level rises slightly in the graduated cylinder.

Ask students:

- **In the animation, you saw that as water is heated the water level rises. Hot water takes up more volume, but the mass stays the same. What does this tell you about the density of hot water?**

Based on the animation, students should understand that the spreading apart of the molecules increases the volume but does not affect the mass of the water. Students should realize that increasing the volume without increasing the mass is going to decrease the density.

- **How does this help explain why hot water floats on room temperature water?**

The less-dense hot water floats on the more dense room temperature water.

## **EXTEND**

### **5. Do a demonstration to show students how dense cold water causes mixing.**

Tell students that in winter, ice can form on the tops of ponds and lakes. In the spring when the ice melts, the cold water sinks. This causes mixing from the bottom which brings nutrients up to the surface. Tell students that you will model this process.

## Materials

- Room temperature water
- Ice cubes
- 2 identical tall clear plastic cups
- Small cup
- Food coloring, any color other than yellow
- Dropper
- Sheet of plain white paper



## Procedure

1. Fill two tall clear plastic cups about  $\frac{3}{4}$  of the way with room temperature water.
2. Place about 15 drops of food coloring into a small empty cup.
3. Use a dropper to pick up the food coloring. Then carefully push the dropper into the water until the tip of the dropper is near the bottom of the cup.
4. Very gently squeeze the dropper so that all of the food coloring slowly flows to the bottom of the cup. Then carefully remove the dropper to prevent food coloring from mixing into the water. (It is ok if a little coloring gets mixed in the water.)
5. Repeat steps 2–4 for the other cup of water.
6. Gently place two ice cubes in the water in one of the cups. (Avoid agitating the water.)
7. Place a piece of white paper behind each cup and observe.

## Expected results

The coloring in the cup with the ice will move up from the bottom and begin to mix throughout the water. The coloring in this cup will mix faster than the coloring in the cup without ice.

Ask students:

- **The food coloring mixed more quickly in the cup that had the ice. Use what you know about the density of water at different temperatures to explain why this happened.**

Ice is about 0 °C and the water in the cup is about 20 °C. As the ice melts, the water from the melted ice is colder than the water around it. This colder water is also more dense, so it sinks to the bottom. This sinking water pushes the food coloring out of the way, causing mixing.