**Lesson 11 – Connecting Changes in Temperature and Density to Sinking and Floating**

**Storyline Summary:**

Review the concept that changing the volume of an object, while keeping mass constant causes the density to change. Be sure students understand that heating and cooling a substance causes this result. The connection between temperature and density is key as students will need to understand this relationship to explain how "blobs" can both rise *and* sink in the Lava Lamp system.

Students know that the volume of the blobs is changing by heating and cooling and that their density must be changing and that’s why they float and sink in the surrounding liquid. Let students know that they will see this in action in this lesson.

Discuss how students might model mass as constant and volume as variable. Students can then return to their Lava Lamp model to add changes in density caused by temperature. They should add captions and notations to explain *why* and *where* "blobs" would heat up, expand, become less dense and rise, and when they would cool down, contract, become more dense, and sink.

You could return to the "floating carrot" demonstration to allow for discussion about *what* had to be changed to get a sinking carrot to rise and float in that demonstration and how the Lava Lamp is different.

In the carrot experiment, the *mass* of the water was increased by adding salt. This made the water *more dense* and the carrot floated. The Lava Lamp example uses a different method to get the same result. In the Lava Lamp, the *volume* of the blob increases when it is heated so it becomes *less dense* than the liquid around it so the blob floats.

Extending the discussion to include examples of "convection" beyond the Lava Lamp can be a useful bridge for additional exploration of ocean currents, weather, and the rock cycle.

**What Students Do**

Students observe and discuss a teacher demonstration of hot water placed on cold water, and then cold water placed on hot water. Students also conduct an experiment by using a dropper to insert hot and cold colored water into room temperature water.

**What Students Learn**

* Faster-moving molecules move further apart, volume increases, density of the substance decreases causing the substance to float.
* Slower-moving molecules move closer together, volume decreases, density of the substance increases causing the substance to sink.

**Materials & Preparation:**

***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

**Temperature Affects Density**

(From Middle School Chemistry, Chapter 3, Lesson 6)

***Key Concepts***

* Heating a substance causes molecules to speed up and move slightly further apart, occupying a larger volume that results in a decrease in density.
* Cooling a substance causes molecules to slow down and move 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 molecular motion and spacing to density. Students have seen that as a substance is heated, 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
* Paper towels
* Water-resistant card (from a deck of cards or laminated index card)

# ENGAGE

1. **Discuss the types of movement students have observed and studied to understand the Lava Lamp phenomena.**

**There are three. 1. Micro, 2. Macro, and 3. Systems.**

On the *micro* level we have Kinetic Energy, the movement of molecules which increases and decreases with heating and cooling.

On the *macro* level students have seen the semi-solid substance at the bottom of the lamp expand when heated, seem to change from a solid to a liquid, and then the blobs rise and sink.

On the *system* level, students have also investigated the structure of the lamp itself, how it produces heat and how that heat is transferred to the contents of the lamp.

Now students explore in more detail how heating and cooling affect the density of the blobs which causes BOTH rising *and* sinking of the *same* substance within the system. Let students know that this will be the last set of experiments and observations to add to everything they have done before to complete their understanding of how the Lava Lamp works.

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

Tell students that in previous lessons 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.

## 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.

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?

### Procedure

### Cold water on top

1. 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.

# EXPLORE

# 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 ⅔ 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.

## 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

## 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.

The key point is that heating a liquid causes its molecules to move faster and further apart, making it less dense. Cooling a liquid causes its molecules to move slower and closer together, making it more dense. The hotter less dense water floats on the room temperature water. The colder more dense 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.

1. **Guide a discussion about how temperature affects the rising and falling of the liquid blobs in the Lava Lamp**

Ask students:

* **What do you think is changing about the blobs that cause them to both rise and sink?**

Since the mass of the blobs stays the same but the volume changes, students should conclude that the *density* of the blobs changes with temperature. Invite students to use Talk Moves to discuss initial ideas of how changes in volume affect changes in density.

1. **Have students revise their models.**

Students should revise their models to add an understanding of a change in density due to a change in temperature. Students should show that volume of the blob expands when heated, causing the density to decrease and the blob to rise; and that the volume of the blob contracts when cooled, causing the density to increase and the blob to sink.

If you’ve studied convection currents, Lava Lamp models might now show convection currents defined by the moving blobs rising and sinking due to density that changes with temperature.

Students can show motion lines for hotter and cooler blobs and spacing between dots. Students can also use color to indicate relative temperature. Students can also show a zoom-in to show kinetic energy and spacing of molecules.

Discuss that sometimes models emphasize the differences between two situations to show that there is a difference even though the degree or amount of difference shown may not be accurate.

Discuss ways to handle this through descriptive labeling of student models to address the problem of small differences in relative speed and spacing.

**EXTEND**

Let students know that they now have all the science concepts, information, and evidence from experiments they need to make a complete model of the Lava Lamp. Tell students that in the next class they will include everything they can to make their model as complete, clear, and detailed as possible. They will show the different structures of the lamp and how they function to affect the contents of the lamp on the macroscopic and molecular level and how this affects the rising and falling of the blobs that we see.