**Lesson 8 – Exploring Kinetic Energy**

**Storyline Summary:**

At this point, students know that heating the contents of the Lava Lamp has an effect on the movement of the blobs. Students also know that the rising and sinking of the blobs is related to their density.

In this lesson, students investigate molecular motion (kinetic energy) and see that heating makes molecules move faster and further apart, and that cooling causes molecules to slow down and get closer together. Students can conclude that heating and cooling affect the density of a substance.

Students make sense of their observations by modeling their understanding using dots or circles, motion lines, and color. Students can extend their thinking by moving their bodies quickly or slowly to model how the motion of molecules relates to the temperature of a substance.

**What Students Do**

Students design an experiment using hot and cold water and food coloring to explore whether adding energy (heating) and removing energy (cooling) affects the motion of molecules in a substance.

**What Students Learn**

* + Molecules are in motion in solids, liquids, and gases.
	+ Adding energy (heating) increases molecular motion.
	+ Removing energy (cooling) decreases molecular motion.
	+ Faster moving molecules move a little further apart.
	+ Slower moving molecules move a little closer together.

**Materials & Preparation:**

* DQB
* Student Lava Lamp Models
* KE dance
	+ Hot water (about 50 °C) in a clear plastic cup
	+ Cold water in a clear plastic cup
	+ Yellow food coloring in a small cup
	+ Blue food coloring in a small cup
	+ 4 droppers

**Note:**

The focus of the story now is on the concept that adding energy (heating) increases molecular motion, and that removing energy (cooling) decreases molecular motion. The increase in spacing between molecules that are heated and the decrease in space between molecules that are cooled is also important to note and discuss and will be emphasized in up-coming lessons.

**ENGAGE**

* + 1. **Discuss with students how exploring a liquid that is heated and cooled might help them better understand the behavior of the blobs in the Lava Lamp.**

By this time, students should have a good idea that heating the blob material causes it to become less dense and float, and cooling makes it more dense and sink. Let students know that the next three lessons will help explain why this happens on the molecular level.

**Molecules on the Move**

(From Middle School Chemistry - Chapter 1, Lesson 2)

Ask students to design an experiment to investigate the speed of water molecules in two cups of water at different temperatures.

Ask students questions such as the following:

* **Do you think the speed of water molecules might be different in hot and cold water? What can we do to find out?**
Students may guess that molecules in hot water move faster. There are several possible experiments that students might suggest for finding out if this is true. One of the more obvious ones is to heat water a lot so that it boils. Then you can see the water moving. You could do this, but it requires a hot plate, takes a fair amount of time, and may have to be done as a demonstration instead of being an activity that students can do.

Tell students that one possible method is to use hot water and cold water and add food coloring to the water. If the water molecules move faster at one temperature than another, the food coloring should move faster too and make the movement easy to see.

Ask students:

* **Should we use the same amount of hot and cold water in our experiment?** Yes.
* **Should we use the same type of cup for the hot and cold water?** Yes.
* **Should we use the same number of drops of food coloring in each cup?** Yes.
* **Should we put the coloring in at the same time?** Yes.

Explain that the different things like the amount of water, type of cup, and number of drops of food coloring are called **variables**. It is important to keep all the variables the same except for the one you are testing. Because we are trying to find out if temperature affects the motion of water molecules, we should keep everything else about the experiment the same except for the temperature. Temperature should be the only variable that is different in the two samples. This way, if we notice something different between the two samples of water, we will know that the difference in temperature is causing it.

**EVALUATE**

Give each student an activity sheet.
Students will record their observations and answer questions about the activity on the activity sheet. The Animation 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.

As students complete the activity sheet, review student work for the understanding of the effect of heating and cooling on molecular motion. These should be indicated with greater or fewer motion lines and be incorporated as an additional detail in their model.

**EXPLORE**

1. **Do an experiment to compare the speed of water molecules in hot and cold water.**

**Question to investigate**Is the speed of water molecules different in hot and cold water?

**Teacher preparation**

This activity works best if there is a big difference between the temperatures of the hot and cold water.

1. Squirt 4–5 drops of blue food coloring into a small cup for each group.

2. Squirt 4–5 drops of yellow food coloring into another small cup for each group.

3. Add ice to a container and then add about 6 cups of tap water to make it sufficiently cold.

4. Pour about ¾ cup of cold water (no ice) into a cup for each group.

5. Pour about ¾ cup of hot water into a cup for each group.

**Materials for each group**

* + Hot water (about 50 °C) in a clear plastic cup
	+ Cold water in a clear plastic cup
	+ Yellow food coloring in a small cup
	+ Blue food coloring in a small cup
	+ 4 droppers

**Procedure**

1. With the help of your partners, use droppers to carefully place 1 drop of yellow and 1 drop of blue food coloring into the hot and cold water at the same time.

2. Allow the colors to mix on their own. **Do not stir**. Watch the cups for a couple of minutes.

**3. Record and discuss student observations.**Give students time after the activity to record their observations by answering the following questions on their activity sheet. Once they have answered the questions, discuss their observations as a whole group.

* + **Describe what the colors looked like and how they moved and mixed in the cold water.**
	+ **Describe what the colors looked like and how they moved and mixed in the hot water.**
	+ **What does the speed of the mixing colors tell you about the speed of the molecules in hot and cold water?
	Expected Results**The yellow and blue food coloring will spread faster in hot water than in cold. The colors will combine and turn green in the hot water while the colors will remain separate longer in the cold water. Students should agree that the food coloring mixes faster in the hot water because the molecules in hot water move faster than they do in cold water.

**EXPLAIN**

1. **Show an animation of water molecules at different temperatures.**

Show the molecular model animation ***Heating and Cooling a Liquid***.<www.acs.org/middleschoolchemistry/simulations/chapter1/lesson2.html>
Move the slider at the bottom of the window all the way to the right to show that the water molecules are moving faster and are a little farther apart in hot water.

Explain that the little balls represent the particles of a liquid, in this case water molecules. Let students know that for now, they will use circles or spheres to represent atoms and molecules, but eventually they will use a more detailed model. For now, students should focus on the motion of the molecules, how they interact, and their distance from one another.

Ask Students:

* **Are the molecules moving faster in cold or hot water?**Students should realize that the molecules of hot water are moving faster. The molecules of cold water are moving slower.
* **How does this match with your observations with the food coloring?**The food coloring in the hot water mixed faster than the coloring in the cold water did.
* **Look closely at the space between the molecules in cold and hot water. Is there more space in between the molecules in hot water or in cold water? Is it a lot of space?**Point out to students that molecules of hot water are moving faster and are slightly further apart. The molecules of cold water are moving slower and are a little closer together. If students do not notice a difference, move the slider all the way to the left again and then to the right. Show the animation a few times to give students a chance to notice the differences.

**5. Have students answer questions about the animation and draw a model of water molecules on their activity sheet.**Have students fill in the blank with the word *increases* or *decreases* on their [**activity sheet**](https://www.middleschoolchemistry.com/pdf/chapter1/1.2_student.pdf) as you read each sentence.

* + **Heating a substance increases molecular motion.**
	+ **Cooling a substance decreases molecular motion.**
	+ **As molecular motion increases, the space between molecules increases.**
	+ **As molecular motion decreases, the space between molecules decreases.**

Project the image ***Water Molecules at Different Temperatures***[www.acs.org/middleschoolchemistry/simulations/chapter1/lesson2.html](https://americanchemicalsociety.sharepoint.com/sites/SBSDepartment/Web%20Services%20Team/Education%20Projects/Middle%20School%20Chemistry/Storyline%20Approach/Lava%20Lamp/LL%20Lesson%208/www.acs.org/middleschoolchemistry/simulations/chapter1/lesson2.html)Have students refer to the drawing of room temperature water on their activity sheet and discuss how they should represent the molecules in cold and hot water.

****For **Cold Water**
Ask students:

* **Would the water molecules be closer together or further apart?**
Students should draw the circles a little closer together than the circles in the room-temperature water. The water molecules are closer together because the slower motion allows the attractions to bring the molecules a little closer together.
* **Would there be more or fewer motion lines?**
Students should realize that since the molecules in the cold water are moving slower, they should have fewer motion lines than the molecules in room-temperature water.

The slower motion also allows the attractions to bring the molecules a little closer together than in room temperature water, so the circles should be drawn a little closer together.

For **Hot Water**Ask students:

* **Would the water molecules be closer together or further apart?**Students should draw the circles a little further apart than the circles in the room-temperature water. The faster motion competes with the attractions water molecules have for each other and causes the molecules to move a little further apart.
* **Would there be more or fewer motion lines?**Students should realize that since the molecules in hot water are moving faster than in cold or room-temperature water, they should draw more motion lines.
* **What evidence do you have from your experiment to show that the speed of the water molecules is different in hot water?**

Since the food coloring turned green faster in hot water, the water molecules must have been moving faster and mixed the colors faster than in cold water.

Consider using movement as a model. Students can act as water molecules and move to the tempo of two songs with different tempos, slow and fast. Examples might be “Ravel’s Bolero”, and “The Flight of the Bumblebee”. Instruct students to move around the space to the tempo of the song for a short period of time, such as 1 minute. The teacher or a student volunteer can hold colored streamers to model the food coloring molecules mixing slowly or quickly.

In the diagram, the graduated cylinder on the left was filled with 100 milliliters of water at room temperature (22 °C). This water was then heated to 100 °C and poured back into the graduated cylinder.

* **How can you explain the difference in volume between the two samples of water?**

The heat increased the motion of the water molecules so much that their motion competed with their attractions and caused them to spread apart so that the water took up a greater volume.

**EXTEND**

1. **Guide a discussion to combine ideas about kinetic energy, motion, and spacing of molecules to describe the first step of melting after the Lava Lamp is turned on.**

Ask students to use the principles they’ve learned to describe, on the molecular level, what they think is happening to the solid blob at the bottom of the Lava Lamp when the bulb is first turned on.

Students should have noticed that after the bulb is turned on, the blob material at the bottom expands to form a dome and eventually changes from a semi-solid waxy material into liquid blobs.

Students should realize that the heat from the bulb causes the molecules in the blob to move faster and a little further apart making the material expand as a dome. As the material continues to be heated, the molecules move fast enough to overcome their attractions as a solid and melt to become a liquid.

If students don’t conclude that the solid/semi-solid material at the bottom melts and changes to a liquid, you can discuss the process of melting.

**Note:** The most common example of melting, ice changing to liquid water, can be confusing to use as an example here. When solid ice is warmed and melts to form liquid water, the volume of the liquid water actually *decreases* compared to its volume as solid ice. This is the opposite of what happens in the lava lamp where the solid waxy substance melts, forming a liquid which takes up *more* volume than it did as a solid.

If students don’t offer an explanation, you can explain the process of melting in the Lava Lamp: When the semi-solid waxy substance is heated, its molecules move fast enough that they overcame their attractions, get a little further apart, move more freely past each other, and change from a solid to a liquid.

1. **Revisit the DQB to have a class discussion about investigating heat transfer.**

Tell students that they have seen that heating increases molecular motion and begins the process of melting the blob material. Ask students how they think heat gets from the hot bulb in the bottom of the Lava Lamp to the blob material inside. Ask them if this is important to figure out and eventually add to their Lava Lamp model.

Students should agree that this is an important part of their models and that it will be explored in the next lesson.