

Moving Molecules—The Kinetic Molecular Theory of Heat

Purpose:

The purpose of this lab is for students to determine the relationship between temperature and speed of molecules in a liquid.

Key Science Topics:

- Kinetic Molecular Theory of Heat
- Temperature scale conversion
- Heat vs. temperature

Grade Level:

- Physical Science, Grades 6-9

Student Prior Knowledge:

- Students should be able to define the Kinetic Molecular Theory of Heat.
- Students should know how to convert between Celsius, Fahrenheit, and Kelvin.
- Students should know the difference between heat and temperature.

Materials:

Each lab group should have the following:

- Three beakers labeled A, B, and C
- One color of food coloring
- Colored pencil or crayon that matches the color of the food coloring
- Hot water
- Iced water, be sure not to get any ice in beakers.
- Room temperature water
- Timer

Suggestions:

To begin the lab, I have students record the temperature of the room temperature water and begin recording data for that beaker. As students are recording data, I circulate throughout the room and pour cold water into each groups' beaker. As I am doing this, I am heating up water in the lab microwave. The water temperature should be hotter than room temperature, but not hot enough to cause injury. I have also done this lab while teaching in a math classroom and have had a coffeemaker on hand to heat the water. If you do not have enough glass beakers for every group, make sure the hot water beaker is glass, and the rest can be made of plastic.

Background: Heat & Temperature

Heat and temperature are related, but they're not the same. Heat is another name for *thermal energy*, the energy contained in the vibrations of atoms and molecules. The amount of heat in a substance is the total vibrational energy of all the atoms and molecules that make up the substance. Even substances we think of as freezing cold, like ice, have a lot of heat.

Put a pot of water on the stove, turn on the burner, and watch it. You're adding heat, so the total vibrational energy of the water rises.

So what is temperature?

Temperature is *not* energy, but rather the average heat in a substance, or the amount of heat *per molecule*.

Fill a tub with water, and scoop some out with a cup. Both the tub and the cup now contain water at the same temperature. But because the tub contains *much more water*, it also contains *much more heat*!

Why does temperature matter?

Temperature tells us how heat *flows*. If we take two objects of any size with different temperatures and put them in contact with each other, heat will flow from the one with higher temperature to the one with lower temperature. The amount of heat does not change, but its distribution does, as energy is transferred from the warmer object to the colder one.

To cool a warm glass of water, add ice. The glass of warm water starts with a good bit of heat. Ice also has heat, although not as much as liquid water, so *adding* ice actually makes the amount of heat in the glass *rise*. Once the ice is added, the amount of heat in the glass is fixed. At that point, the difference in temperature between the warm water and the cold ice requires heat to flow from the water into the ice. Removing heat from the *water* makes its temperature *fall*, while putting heat into the *ice* makes its temperature *rise*. This flow of heat continues until the ice melts and mixes with the water. The result is a glass of water that is both colder and fuller than it was before we added the ice.

Although water molecules are too small to see, we can detect and measure their movement. In this lab, food coloring will be used a "molecular movement detector." Students will place a drop of food coloring in three beakers of water at different temperatures. Students will observe the motion of the food coloring and infer the motion of the molecules.

Caution: Students will want to look at the ribbons of food coloring. Emphasize that they are looking for the clear water to turn a slight tinge of color. See photograph below:

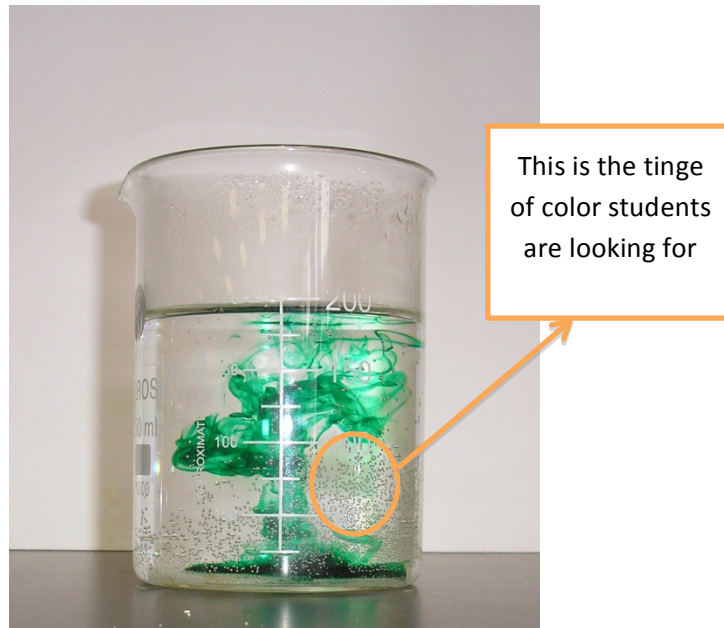


Figure 1: The above photo shows the ribbons of food coloring as well as the tinge of color students are looking for. Students should stop the timer when they see an area that looks like the circled region. Student sketches should illustrate the ribbons of food coloring, plus the area that turns color first. Photo Credit: D. French

Summary:

Heat is the energy an object has because of the movement of its atoms and molecules which are continuously jiggling and moving around, hitting each other and other objects. When we add energy to an object, its atoms and molecules move faster increasing its energy of motion or heat. Even objects which are very cold have some heat energy because their atoms are still moving.

Common Core Standards

Insert applicable common core standards here.

Next Generation Science Standards

Insert applicable NGSS here.

Moving Molecules—The Kinetic Molecular Theory of Heat

Name: _____

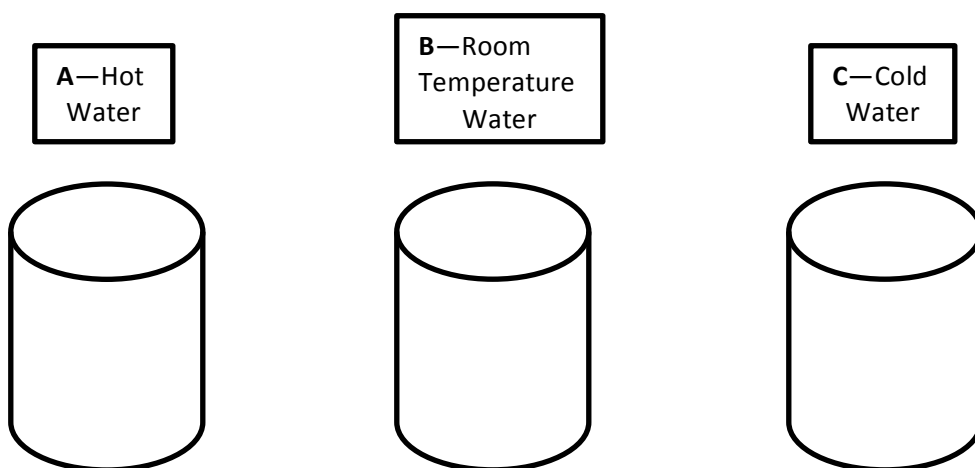
Date: _____

Purpose:

Materials:

Procedures:

1. Get three identical glass beakers and label beakers A, B, and C.
2. Pour 200mL of hot water in Cup A. Record the temperature of Cup A _____
3. Pour 200mL of room temperature water in Cup B.
Record the temperature of Cup B _____
4. Pour 200mL of iced water in Cup C. Be sure not to include the ice.
Record the temperature of Cup C _____
5. Using one color of food coloring, carefully squeeze one drop of food coloring on the surface of the water in each beaker. Try not to disturb the water. Start the timer as soon as the food coloring is dropped.
6. Observe how the food coloring behaves in each of the three beakers. The food coloring will separate out into “ribbons.” This is not what you want to focus on. Stop the timer when the clear water turns just a tinge of color. Record the time it took for the clear water to turn color in the graph below.
7. Sketch your observations for the beakers below. Use a corresponding colored pencil to depict the color spreading in each beaker.



Beaker	Observed Temperature, °C	Convert to K	Convert to °F	Time it took for water to change color (s)
A				
B				
C				

1. What was the independent variable in this experiment?
2. What was the dependent variable in this experiment?
3. Which beaker was the control? In other words, which beaker did you compare the other two beakers to?
4. List at least two (2) constants in this experiment:
5. What caused the food coloring to move in the water?
6. In which beaker did the water change color first? Explain using the Kinetic Molecular Theory of Heat.
7. Explain the difference between *heat* and *temperature*?
8. Predict what would happen if you left the three beakers rest on your table overnight. What would the water look like? What would the water temperature be?
9. Write a conclusion sentence stating the relationship between the *temperature* and the *speed of molecules* moving in the water.

Moving Molecules—The Kinetic Molecular Theory of Heat

Name: Key

Date: _____

Purpose:

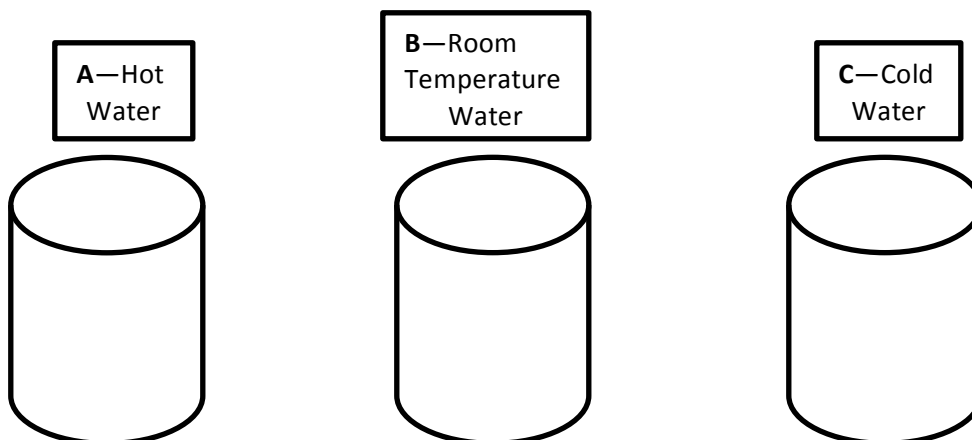
The purpose of this lab is to determine the relationship between temperature and the movement of molecules in a liquid.

Materials:

- Three beakers
- 1 bottle of food coloring
- Stopwatch
- Colored pencil
- Cold, room temperature, and hot water

Procedures: **Sample Data**

8. Get three identical glass beakers and label beakers A, B, and C.
9. Pour 200mL of hot water in Cup A.
Record the temperature of Cup A 67°C
10. Pour 200mL of room temperature water in Cup B.
Record the temperature of Cup B 19°C
11. Pour 200mL of iced water in Cup C. Be sure not to include the ice.
Record the temperature of Cup C 7°C
12. Using one color of food coloring, carefully squeeze one drop of food coloring on the surface of the water in each beaker. Try not to disturb the water. Start the timer as soon as the food coloring is dropped.
13. Observe how the food coloring behaves in each of the three beakers. The food coloring will separate out into “ribbons.” This is not what you want to focus on. Stop the timer when the clear water turns just a tinge of color. Record the time it took for the clear water to turn color in the graph below.
14. Sketch your observations for the beakers below. Use a corresponding colored pencil to depict the color spreading in each beaker.



Beaker	Observed Temperature, °C	Convert to K	Convert to °F	Time it took for water to change color (s)
A-Hot	67°C	340 K	152.6°F	23s
B-Room Temp.	19°C	292 K	66.2°F	47s
C-Cold	7°C	280 K	39.2°F	95s

1. What was the independent variable in this experiment?
Water temperature was the independent variable.
2. What was the dependent variable in this experiment?
The time it took for the water to change color was the dependent variable.
3. Which beaker was the control? In other words, which beaker did you compare the other two beakers to?
The beaker with the room temperature water was the control.
4. List at least two (2) constants in this experiment:
-same thermometer
-same amount of water
5. What caused the food coloring to move in the water?
The movement of the water molecules caused the food coloring particles to move.
6. In which beaker did the water change color first? Explain using the Kinetic Molecular Theory of Heat.
The beaker with the hot water changed color first. The Kinetic Molecular Theory of Heat states that molecules in a fluid increase their speed as temperature increases.
7. Explain the difference between *heat* and *temperature*?
Heat is the total internal kinetic energy of a system and temperature is the average kinetic energy of a system.
8. Predict what would happen if you left the three beakers rest on your table overnight. What would the water look like? What would the water temperature be?
The hot water would lose heat to the surroundings and become room temperature. The ice cold water would gain heat from the surrounds and become room temperature. The food coloring would be evenly dispersed throughout all beakers.
9. Write a conclusion sentence stating the relationship between the *temperature* and *speed of molecules* moving in the water.
As the temperature of the water increases, the speed of the molecules increases.