Demonstration: What is Temperature?

FOR THE TEACHER

Summary
In this demonstration, students will observe food dye mixing with water at different temperatures.

Grade Level
Middle and High School

NGSS Alignment
This activity will help prepare your students to meet the performance expectations in the following standards:

- **MS-PS1-4:** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- **HS-PS1-5:** Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- **HS-PS3-2:** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
- **Scientific and Engineering Practices:**
  - Analyzing and Interpreting Data
  - Engaging in Argument from Evidence

Objectives
By the end of this demonstration, students should be able to

- explain how temperature is related to average kinetic energy
- provide evidence and explain what temperature measures

Chemistry Topics
This demonstration supports students’ understanding of

- Particle Motion
- Temperature
- Average Kinetic Energy

Time
**Teacher Preparation:** 10 minutes
**Lesson:** 20 minutes

Materials
- Beaker* (100-600ml) with room temperature water
- Beaker* (100-600ml) with ice water
- Beaker* (100-600ml) with hot water
- Blue or green food dye
- *Beakers can be substituted for plastic cups or glass jars.

Safety
- Students should wear proper safety gear during chemistry demonstrations. Safety goggles and lab apron are required.
• Use caution when handling hot water.

Teacher Notes
• This lesson fits well when introducing ideas of energy and heat. It reveals students’ preconceptions about temperature and heat, and challenges the idea that temperature is the measure of how hot or cold something is.
• Temperature is not a measure of heat. At this stage it is essential that all students are clear that temperature is a measure of average KE, and not a measure of heat.
• You may want to ask students to draw particle diagrams to show the relative kinetic energy of cold, room temperature, and hot particles.
• This experiment works best when the ice water is very cold. If the water is not cold enough for a lot of condensation to form on the jar, then it can be hard to distinguish between the room temperature water and the cold water.
• A good way to get very cold water is to fill a large container completely full with ice and then add water. After letting the ice and water sit for several minutes, pour the water into the beaker or jar that you will use for the lab.
• For better viewing, you may want to gently wipe the condensation off the ice water beaker. Make sure not to disturb the water and dye in the beaker.
• This demonstration could be modified to use as a lab activity with high school students.

Procedure
1. Prepare each beaker as described in the materials section.
2. Place 1 drop of food dye in each of the beakers.
3. Record your observations every 2 minutes for 5-7 minutes. Do not disturb!
4. [Optional] Record your observations again at the 20 or 30 minute point.

Expected Results:
• The dye in the hot water, where particles have the quickest molecular motion, rapidly dispersed to create a uniform distribution throughout the beaker (the color was the same from top to bottom). The time this takes may vary depending on how hot your water is, but should be within the first minute or two.
• The dye in the ice water, where particles have the slowest motion, started out by sinking to the bottom. The dye slowly mixed with some water, but the distribution was still very uneven at the 7 minute mark.
• In the room temperature water, some of the dye started out by sinking to the bottom. However, by 3 minutes, the dye was mixing with the water. By the 5 minute point, much of the dye was mixed, although the solution was not as uniform as the hot water solution.
• If you chose to have the students observe the reaction at the 20 or 30 minute point, all three beakers should be fully mixed and have a uniform concentration.
• Expected Results photos: The order of the beakers in each photo is: ice water (left), room temperature water (middle), and hot water (right). The times written in bold reflect how much time has passed since the dye was first added to the water.
FOR THE STUDENT
Lesson

What is Temperature?

Directions
1. Complete the data table for "0 seconds" before any food coloring is added to each beaker.
2. Record observations at the 1 minute mark, 3 minute mark, 5 minute mark and 7 minute mark for each beaker.

<table>
<thead>
<tr>
<th>Time</th>
<th>Dye in Room Temp Water</th>
<th>Dye in Ice Water</th>
<th>Dye in Hot water</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 min</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3 min</td>
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<td></td>
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<tr>
<td>5 min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 min</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis
Answer the following questions:
1. Describe what you see happening to the water and food dye in the beaker over time. Include any differences between the different temperature water samples.
2. What macroscopic evidence do you have that particles of liquids must be moving at all times?
3. What conclusion can be drawn about the speed of particle movement and temperature?