UNIT PC

**Developing Ideas**

# ACTIVITY 6: More on Liquids and Characteristic Properties

## Purpose and Key Questions

In Lesson 5 we found that when heating a liquid, the temperature changed until we observed boiling, and then the temperature remained fairly constant. The temperature at which the liquid boils is called the boiling point, and it is a characteristic property of matter. Recall that we noticed the temperature at which the steam changed to liquid water (condensed) was the same as the boiling point. We left with the idea that liquids behave differently than gases. In this lesson we will be investigating the idea of the attraction between particles, whether liquid particles move like gas particles, and what happens when liquids are heated and cooled without going through a phase change.

Key questions for this lesson are:

***Do we have evidence that liquid particles are attracted to each other? If so, what is the nature of the attraction?***

***How do the properties of particles in a liquid compare to the properties of particles in a gas?***

## Initial Ideas

Linus Pauling[1] said, "The best way to have a good idea is to have lots of ideas, and throw the bad ones away." In the spirit of this quote, what are your ideas about the following?

[1] Linus Pauling is the only person to have won two unshared Nobel Prizes in TWO different fields, Chemistry 1954 and Peace in 1962.

What observational evidence would you need to convince someone of the idea that particles in liquids are attracted to each other? Brainstorm with the members of your group and come up with as many different examples of observational evidence as you can. Providing sufficient and convincing evidence is challenging! Be prepared to have a class discussion about your ideas.

## Collecting and Interpreting Evidence

### Exploration #1: Do liquid particles have an attraction to each other?

You will need:

- Dropper of water
- Dropper of ethanol
- Dropper of hexane
- Sheet of wax paper
- Some toothpicks

**STEP 1:** Place a few droplets of water, ethanol, and hexane side by side on a sheet of wax paper.

**STEP 2:** Watch the droplets for a few minutes. Describe and/or draw the behavior of each droplet in Table 1. Leave the last column blank for now.

**Table 1: Three Liquids on Wax Paper**

| Liquid | Observation of droplet on Wax Paper | Inference about attractive force |
|---|---|---|
| **Water** | | |
| **Ethanol** | | |
| **Hexane** | | |

**STEP 3:** Now observe what happens when you poke and drag the water, ethanol, and hexane drops with a toothpick.

**Observations**:

Summarize your ideas by answering the following questions.

What evidence do you have to suggest there are attractive forces between particles in the liquids?

What do the behaviors of the liquid droplets indicate about the relative strengths of the attractive forces between particles? (In other words, which liquid has the strongest attractive forces, which has the weakest?) Explain your reasoning.

**STEP 4:** Your instructor will demonstrate how a stream of water behaves with a magnet, and then with an electrically charged wand, in order to gather evidence about the nature of the attractive forces.

What happens when the magnet is held next to the stream of water?

What happens when the electrically charged wand is held next to the stream of water?

What does that suggest about the kind of force that exists between particles of water—magnetic or electrostatic? What is your evidence?

**STEP 6:** Suppose the instructor performed a similar experiment using a stream of hexane, rather than water.

Predict what you will observe when a charged wand is brought near a stream of hexane.

**STEP 7:** Observe the demonstration.

What happens when the charged wand is held next to the stream of hexane? How does that compare with what happened with the stream of water?

Make a claim about the attractive forces between the particles in water, ethanol and hexane. Support your claim with evidence.

## Exploration #2: Do liquid particles move?

**Predict**

Imagine that a drop of food dye is added to a beaker containing water. You then observe the food coloring several times over a ten minute period as it sits undisturbed. (It was not stirred.) Using a nanoscopic model (particles) predict what you think you will observe over time. (Don't forget to include your reasoning.)

You will need:

- 100 mL beaker with room temperature water
- 100 mL beaker of cold water
- 100 mL beaker of hot water
- Blue or green food dye

**STEP 1:** Place 1 drop of food dye in each of the beakers.

**STEP 2:** Record your observations every 3-4 min for 8-9 min. Do not disturb!! (WHILE WAITING: Start setting up materials for Exploration #3.)

| Time | Dye in Room Temp Water | Dye in cold Water | Dye in Hot water |
|---|---|---|---|
| 0 min | | | |
| 3 min | | | |
| | | | |
| | | | |

Once you have completed your observations, answer the following questions.

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.

What macroscopic evidence do you have that there must be space separating particles of liquids?

What macroscopic evidence do you have that particles of liquids must be moving at all times?

Provide an explanation to account for any differences in behavior of the dyes at different temperatures.

### Exploration #3: Investigating More Macroscopic Properties of Liquids

**Predict**:

Which of the following macroscopic properties will change as a result of heating or cooling liquids? (Select all that apply.) Discuss your thinking with your neighbors, and decide which of the responses best represents your thinking.

A. temperature changes
B. volume changes
C. mass changes

In this experiment we are going to test what macroscopic properties change as a result of heating a liquid. The liquid we will use is the alcohol in a thermometer. The thermometer provides a convenient container to observe the measurements we need.

You will need:

- Alcohol thermometer
- Beaker of hot water

- Beaker of room temperature water
- Beaker of ice water
- Balance (accurate to 0.01 g)

**STEP 1:** Find the mass of the thermometer. Record it in Table 2.

**STEP 2:** Place the thermometer in the room temperature water and record the temperature in Table 2

**STEP 3:** Place the thermometer in the hot water, and when the temperature is stabilized, record the value in Table 2

**STEP 4:** Dry the thermometer quickly and find the mass. Record it in Table 2

**STEP 5:** Place the thermometer in the ice water and when the temperature is stabilized, record the value in Table 2

**STEP 6:** Dry the thermometer quickly and find the mass. Record it in Table 2

**Table 2: Heating and cooling alcohol in the thermometer**

| | |
|---|---|
| Initial Mass of Thermometer ______________ g | Temperature of *Room Temp* Water______ °C |
| Thermometer Mass after heating ____________ g | Temperature of Hot Water ____________ °C |
| Thermometer Mass after cooling ____________g | Temperature of Ice Water ____________ °C |

Answer the following questions to summarize your findings

What happens to the volume of the liquid in the thermometer as it is heated in the hot water? What is your evidence?

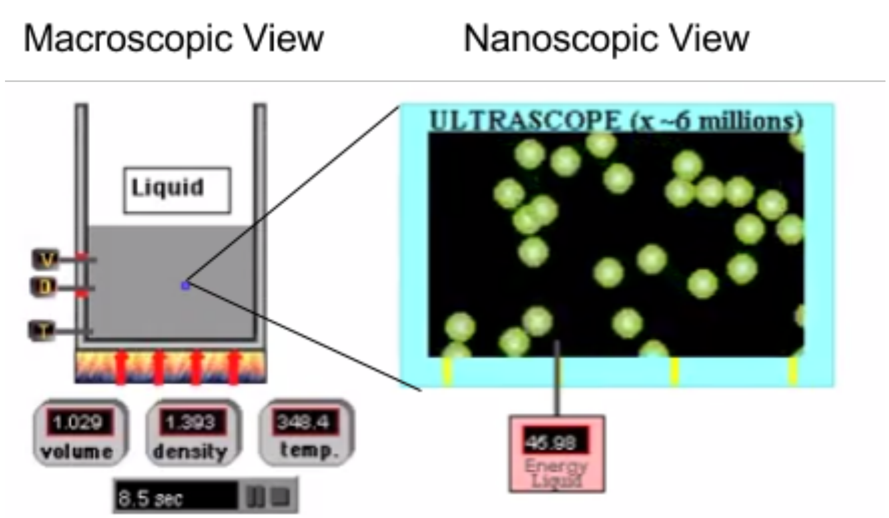
What happens to the volume of the liquid in the thermometer as it is cooled in the cold water? What is your evidence?

What happens to the mass of the liquid in the thermometer as it is heated and cooled?

Provide an explanation in terms of the liquid particles that can account for any of the changes that you observed.

## Exploration #4: Investigating Particle behavior and energy in Simulator

**STEP 1:** In your groups, watch the movie of the simulation of a liquid being heated that simulates the thermometer in hot water (***UPC A6 Movie Liquid Heated Sim***). Below you will see a picture of the simulation used. Notice that on the left there is a macroscopic representation of the liquid, and a nanoscopic view of a small portion of the liquid on the right.

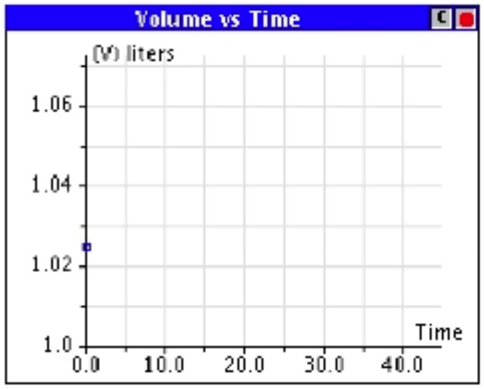


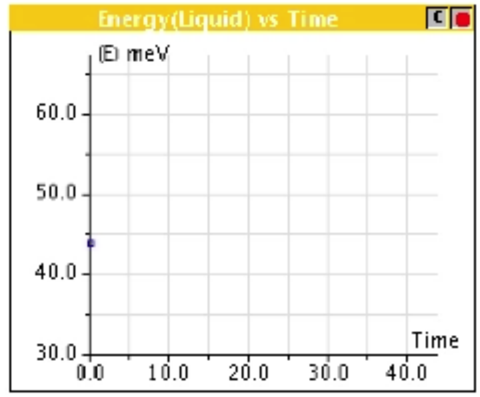

Pay close attention to particle size and motion. During the movie the temperature of the liquid increases from 340° K to 380° K (an increase of 40° K or 40° C).

Record your observations.

Answer the following questions.

Sketch the volume versus time graph and the average kinetic energy of the particles versus time graph for the liquid being heated.




As the temperature of the liquid is increased, what happens to the average kinetic energy of the particles?

What happens to the (macroscopic) volume of the liquid as it is heated?

The simulator suggests that as the liquid is warmed the particles do not change in size. Therefore, what must happen to the space separating the particles as the liquid warms—decrease slightly, increase slightly, or remain the same?

What do you think happens to the mass and total number of particles as the liquid is heated? What evidence supports your answer?

What do you think happens to the potential energy of the liquid particles as the liquid is heated?

**STEP 2:** Watch the animation on Potential Energy (***UPC A6 Book on Shelf Animation***) due to putting a book on a shelf.

It takes energy to move the book up to the shelf; where did the energy go?

What happened to the potential energy when the book fell off of the shelf?

How would you explain potential energy to a friend?

Use the idea of potential energy to describe the energy involved with particles during phase changes. (Remember that the particles are attracted to each other by an attractive electrostatic force.)

**STEP 3:** Now watch an animation simulating the electrostatic attraction (***UPC A6 Charge PE Animation***) between two oppositely charged particles.

When energy is added to the system of oppositely charged particles, where does that energy go?

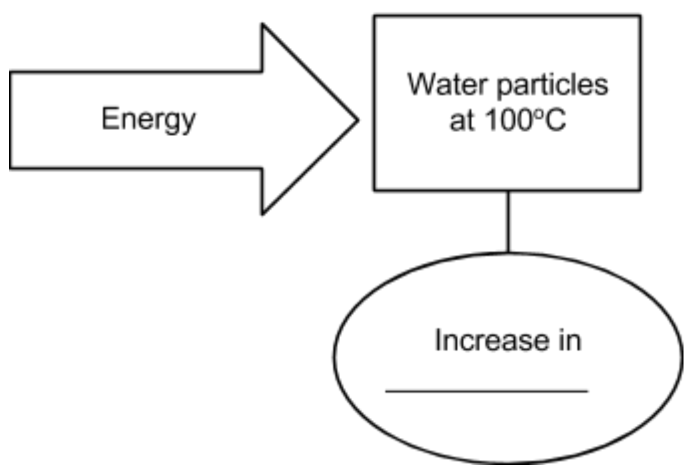
What happens to the energy when particles that are attracted to each other move closer together?

Recall that methanol has a boiling point of 64.7C and water has a boiling point of 100C. What does that tell you about the attractive electrostatic forces between methanol particles and those between water particles?

Explain why the temperature doesn't seem to change much when the water is boiling, even though heat energy is being transferred to the water as it is heated.

Below is a Nano energy diagram that represents the energy flow when water is going from a liquid to a gas at its boiling point ($100^{o}$ C at sea level). Fill in the blank to complete the representation.

"Heat" **Interaction**




Draw a nano energy diagram that represents steam condensing at 100° C.

## Summarizing Questions

**S1**. Make claims about liquid vs gas particles in the table below, and provide supporting evidence. Use evidence from any activity or simulation up to this point.

| | **Claim about liquid vs gas Particles** | **Evidence** |
|---|---|---|
| Motion of Particles observed at same temperature | | |
| Space between particles | | |
| Attraction between particles | | |
| Type of attraction | | |

**S2.** Draw a nano energy diagram for liquid water being heated from 20-80° C.

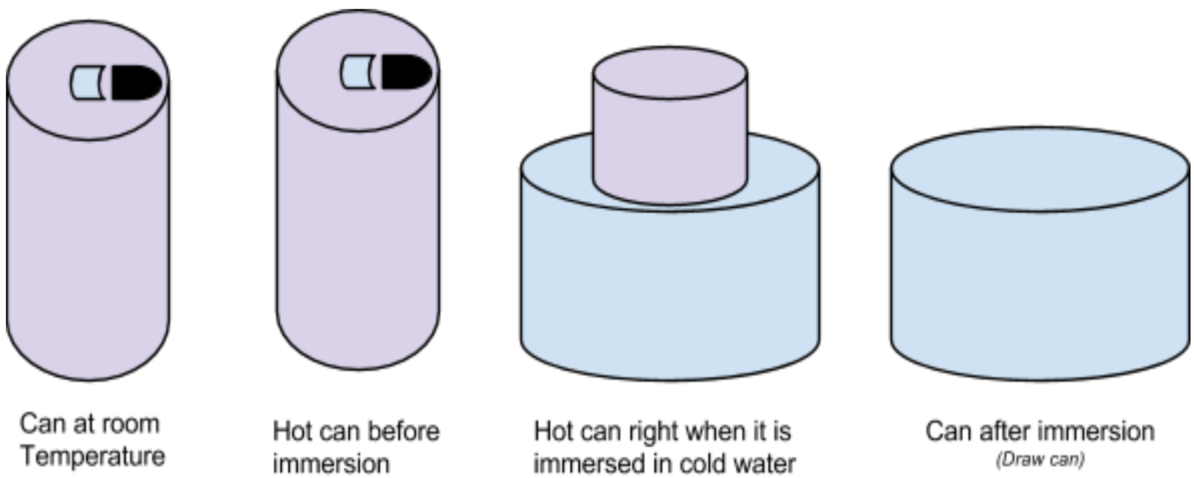
**S3.** Which of the following properties change when a liquid is heated but has NOT yet boiled? Provide evidence and rationale for your claims.

a. Mass
b. Volume
c. Particle size
d. Average kinetic energy of particles
e. Distance between particles
f. Potential energy

**S4.** Two liquids have different boiling points: 100° C and 70° C. Which of these liquids would you expect to have higher attractive electrostatic forces? Explain your answer using evidence.

**S5.** In light of all of the observations you have made thus far, revise your model of the WATER can from Activity 1. Draw what is happening to the particles inside the can throughout the process. Compare the Water Can to the Air Can in terms of the small particles.

**WATER CAN**




**AIR CAN**