Unit PC

LESSON 4: Liquids and the SPT

Purpose and Key Questions

Recall the key ideas of the Small Particle Theory for gases that were discussed in Lesson 2:

- Particles are in constant motion
- Particles move in different directions and with different speeds
- Changes in particle direction and speed occur when particles collide with one another (or other objects)
- The region of space between particles is empty, or void
- Gas particles are much smaller than the space between them
- Gas particles do not attract each other at a distance
- Temperature (in kelvins) ~ average KE of particles
- Pressure ~ [# of particles x Avg. KE]/Volume

Scientists' Small Particle Theory assumes that ***all*** materials, not just gases, are composed of small particles. While some ideas that we developed for gases may have some application to liquids, it is important for us to examine how the Small Particle Theory distinguishes liquids from gases. (In the next lesson we will consider solids and the SPT.) From a previous extension you know that liquids are much denser than gases, and from experience you know that liquids behave differently from gases. In this lesson, we will be adding to this knowledge by making a series of observations related to the macroscopic properties of liquids, including what happens when a liquid is heated or cooled. From these observations, we will be able to make inferences about composition of the liquids in terms of particles and their properties.

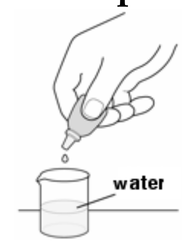
The key questions for this lesson are:

1. ***What evidence supports the idea that liquids are made up of small particles?***
2. ***How are liquids similar to and different from gases in terms of particles?***
3. ***What happens when a liquid is heated or cooled?***

Predictions, Observations and Making Sense

Part 1: What evidence supports the idea that liquids are made up of small particles, and what are some properties of the particles?

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 is not stirred.)



<u>CQ 4-1</u>: What do you predict will happen over time after the food coloring is added?

A. Dye remains a droplet on surface of water.
B. Dye spreads out on the surface of water.
C. Dye spreads out in the bulk water.
D. Dye sinks to the bottom but does not spread out in the bulk water.

To check your prediction, watch **UPC L4 Mov1**, which shows the experiment being done.

Describe what you see happening to the water and food dye in the beaker over time.

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?

Next you will observe the behavior of three liquids on wax paper.

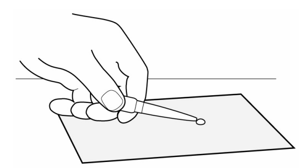
Watch **UPC L4 Mov2**, which shows droplets of water, ethanol, and hexane being placed on a sheet of wax paper.

Describe and/or draw each droplet in Table 1.

Table 1: Three Liquids on Wax Paper

Liquid	Observation of droplet on Wax Paper
Water	
Ethanol	
Hexane	

UPC L4 Mov3 then shows what happens when an attempt is made to move the water and ethanol droplets.



What happens to the water droplet as the dropper is dragged through it—does it smear or does it move as an intact droplet(s)?

What happens to the ethanol droplet as the dropper is dragged through it—does it smear or does it move as an intact droplet(s)?

Consider only the water droplet.

What evidence do you have that attractive forces, other than forces due to colliding and bouncing, exist between particles of water?

Now compare the behaviors of all three droplets.

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

To provide some evidence regarding the nature of the attractive forces within the liquid, watch **UPC L4 Mov4**. In this movie, first a magnet and then an electrically charged wand are held next to a stream of water.

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?

Given the interaction with the charged wand, what does that suggest about the kind of force that exists between particles of water—gravitational, magnetic, or electrostatic? What is your evidence?

Suppose a similar experiment was done using a stream of hexane, rather than water.

CQ 4-2: What do you think you will observe when a charged wand is brought near a stream of hexane?

A. The hexane will bend the same amount as the water toward the charged wand.
B. The hexane will bend less than water or barely at all toward the charged wand.
C. The hexane will bend away from the charged wand.
D. There is no way to predict what the hexane will do.

Watch **UPC L4 Mov5** to see what happens.

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?

Part 2: How do liquids change macroscopically when heated or cooled?

First, make a prediction.

<u>CQ 4-3</u>. Which of the following macroscopic properties do you think will change as a result of heating or cooling a liquid in a closed container? [At this time, do not consider freezing or boiling.]

I. Temperature
II. Volume
III. Density
IV. Mass

A. I
B. I and II
C. I, II, and III
D. I, II, III, and IV

To check your prediction, watch **UPC L4 Mov6**. This movie shows a thermometer being placed in room temperature water, hot water, and cold water. In this case, *volume* refers to the volume of the liquid inside the thermometer (how much space it takes up), and *mass* refers to the mass of just the liquid inside the thermometer.

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?

Do you think the mass of the liquid in the thermometer changes? (It was not directly measured in the movie.) Why or why not?

Does the density of the liquid (mass over volume) in the thermometer change? Why or why not?

Here are some definitions related to liquids:

A macroscopic increase in the volume of a liquid when heated is called **thermal expansion**.

A macroscopic decrease in the volume of a liquid when cooled is called **thermal contraction**.

Part 3: How does the SPT apply to liquids?

CQ 4-4. What do you think happens to particles of a liquid during heating or cooling?

A. Particles get larger or smaller.
B. Particles move faster or slower.
C. Particles may move closer to or further away from each other.
D. Both B and C occur.
E. A, B and C all occur.

In this part you will examine a model of liquids by looking at a simulation of particles of a liquid. First, watch **UPC L4 Mov7**, which is a simulation of particles of a liquid as seen in the Ultrascope view.

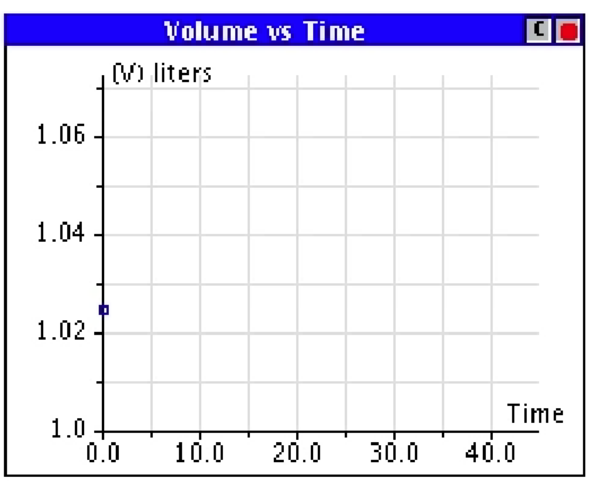
In what way(s) is the motion of liquid particles similar to that of gas particles?

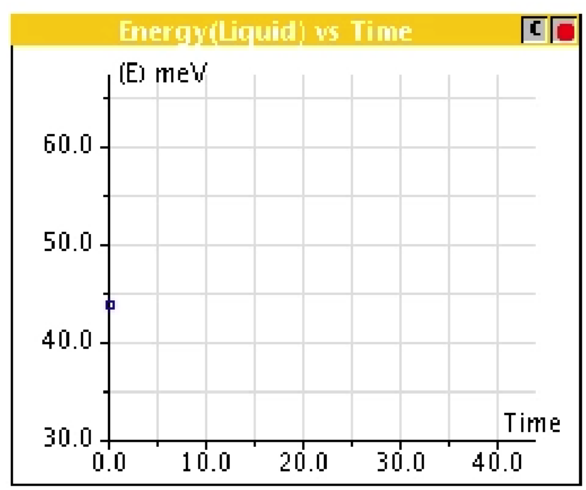
What is between liquid particles? Why do you think so?

On average, are liquid particles closer together or further apart than particles of gases, relative to the size of the particles?

Next, watch **UPC L4 Mov8**, which shows a simulation of a liquid being heated. This simulates the ***thermometer in hot water*** that you saw previously. The simulation shows the container with a liquid in it, an Ultrascope view of the particles inside the liquid, and graphs of volume of the liquid versus time and average KE of the particles versus time. During the movie the temperature of the liquid increases from 340 K to 380 K (an increase of 40 K or 40^{o} C).

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





Answer the following questions based on your observations of the liquid simulator.

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 simulation suggests that as the liquid is warmed, the particles do not change in size. Therefore, what must happen to the average space separating the particles as the liquid warms—does it 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 can you infer happens to the *density* of the liquid as it is heated?

Recall that gas particles are not attracted to one another; rather, they bounce off each other after colliding. Although it may be difficult to see in the simulation, the liquid particles do have an influence on each other even when not touching.

Particles comprising a **liquid** have no apparent organization and are in constant motion. They are close (usually within one to a few particles apart) but can collide and move past each other over some distance. As they move, however, the particles do have some influence on each other over distances. The attractive electrostatic force between particles of a liquid gives rise to many of the physical properties of materials, including their melting points, boiling points, and hence, their physical states (gas, liquid, or solid) at a given temperature. We will be studying these physical properties in a later lesson.

Summarizing Questions

S1. Use the table below to help you compare and contrast the nature of particles of liquids and gases of the same material.

	Claim about Liquid Particles	**Compared to Gas Particles of the same material**	**Evidence (Simulation or Observation)**
Space between particles			
Motion			
Attraction between particles			
Nature of attractive forces (type of interaction)			
What happens to the speed and spacing of particles when the material is heated or cooled?			

S2. Consider the following statements about particles of a liquid and decide which statements are true.

CQ 4-5: Which statements are *true* for liquids?

i. Particles are in constant motion.
ii. Particles are separated by some amount of empty space.
iii. Particles vibrate constantly in a fixed position.
iv. The space between particles is very large in comparison to the size of the particles.
v. Particles collide with some attraction between particles.
vi. The space between particles is small and varies over time.
vii. The space between particles is small and is fixed over time.
viii. Particles have kinetic energy.

A. i, ii, iv, viii
B. i, iii, v, vii
C. i, ii, v, vi, viii
D. i, ii, iii, vii, viii

S3. The following question was asked earlier in the lesson. Answer it again now, based on what you have learned.

CQ 4-6. Which of the following macroscopic properties do you think will change as a result of heating or cooling a liquid?

I. Temperature
II. Volume
III. Density
IV. Mass

A. I
B. I and II
C. I, II, and III
D. I, II, III, and IV