

Chapter 1, Lesson 1: Molecules Matter

Key Concepts

- Chemistry is the study of matter.
- Matter is made up of extremely tiny particles called atoms and molecules.
- Atoms and molecules make up the three common states of matter on Earth—solids, liquids, and gases.
- The particles of a liquid are attracted to one another, are in motion, and are able to move past one another.
- Being a solid, liquid, or gas is a property of a substance.

Summary

Students discuss the meaning of “chemistry” and “matter.” Students investigate a drop of water hanging from a dropper and drops of water beading up on wax paper. They also look at a molecular animation that models the motion of water molecules. Students are introduced to the idea that matter is made up of extremely tiny particles that are attracted to one another.

Objective

Students will describe their observations about water on the molecular level using the idea that water is composed of tiny molecules that are attracted to one another.

Evaluation

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles.

Materials for Each Group

- Water in small cup
- Dropper
- 2 popsicle
- Wax paper
- 2 large index cards (5 × 8")
- Tape

Materials for the Demonstration

- Tall clear plastic cup
- Water (room temperature)
- White sheet of paper
- Food coloring (red, blue, or green)

About this Lesson

You may be able to complete this lesson in less than 1 class period. If you think this will be the case, you can move on to Lesson 2, which is an application of the concepts covered in Lesson 1.

Note: Some solids, liquids, and gases are made of atoms, and some are made of molecules. Since the concepts covered in Chapter 1 apply to both atoms and molecules, the term “particle” is used as a generic term to include both. At this point, it is enough to give students simple working definitions of “atom” and “molecule.” You can tell students that an atom is the smallest building block of matter and that a molecule is two or more atoms connected together. Let students know that even though atoms and molecules are different, in Chapters 1 and 2, they will both be represented by circles or spheres. Chapters 3 and 4 will go into more depth about the structure of atoms and molecules and will use more detailed models to represent them.

ENGAGE

1. Have a discussion about chemistry and matter.

You could begin the first class by leading a short discussion. Ask students what they think the study of chemistry might be about. You can get a sense of student prior knowledge, identify some misconceptions, and just try to get students on the “same page.”

Tell students that chemistry is the study of matter and what matter does. You could go so far as to say that chemistry is the study of stuff and what stuff does on a very small scale. Ask students for the three common types of matter on Earth (solid, liquid, and gas).

Ask students questions such as the following to guide their thinking:

- **What are some examples of matter?**

Tell students that matter is often defined as anything that has mass and takes up space. Continue the discussion by using water as an example.

- **Does water have mass, and does it take up space?**

A bucket of water is pretty heavy to lift. It definitely has mass. It also takes up space in the bucket. Since it has mass and takes up space, water is matter. But that’s just the very beginning. In chemistry, we want to look deeper and find out more about what matter is made of and how it acts.

Give each student an activity sheet.

Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* 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.



EXPLORE

2. Do an activity to explore the attractions water molecules have for each other.

In this activity, students look closely at a drop of water and move drops of water on wax paper. They see that the water holds together well and is not so easy to separate. The goal is for students to begin thinking about water, or any substance, on the molecular level and to conclude that water molecules must be attracted to one another. The reason for these attractions will be dealt with in later chapters.

Question to investigate

Does water hold together well or come apart easily?



Materials for each group

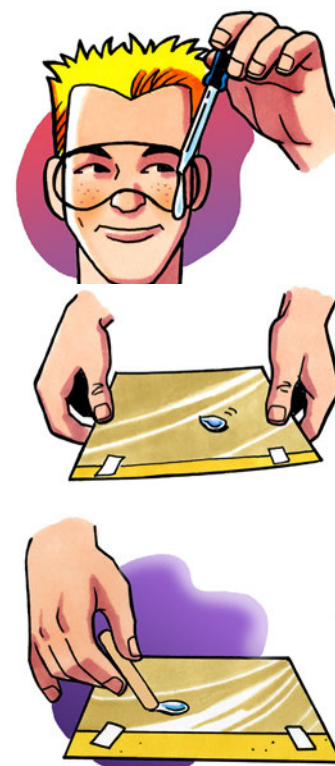
- Water in small cup
- Dropper
- 2 popsicle sticks
- Wax paper
- 2 large index cards (5×8 ")
- Tape

Teacher preparation

Cover a large index card with a piece of wax paper so that the wax paper completely covers the card. Tape the wax paper in place. Prepare two cards for each group.

Procedure

1. Use the dropper to gently squeeze out a drop of water but try not to let the drop fall completely out of the dropper. See how far you can make the drop hang off the end of the dropper without the drop falling.
2. Place 4 or 5 drops of water together on a piece of wax paper to make one medium-size drop.
3. Gently tilt the wax paper in different directions so that the drop moves.
4. Use a popsicle stick to slowly drag the drop around the wax paper a bit. Try using your popsicle stick to separate your drop into two.
5. Use your popsicle stick to move the drops near each other. Then move one drop so that the two drops touch.



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.

- When you squeezed the drop of water out of the dropper, did the water break apart or did it hold together?
- When you tilted the wax paper, did the drop split apart or stay together?
- When you were pulling the drop around the wax paper, did the water seem to hold together or come apart easily?
- When you tried to split your drop, did the drop separate easily?
- What happened when the two small drops touched?

Expected results

The water beads up on the wax paper and stays together when the wax paper is tilted and when the drop is moved around with a straw. It is difficult to separate the drop into two drops. When the drops touch, they combine quickly and easily.

4. Do a demonstration to show that water molecules are in motion.

Materials

- Tall clear plastic cup
- Water (room temperature)
- White sheet of paper
- Food coloring (red, blue, or green)

Procedure

1. Add water to the cup until it is about $\frac{3}{4}$ filled.
2. Ask students to watch closely as you add one or two drops of food coloring to the water. Do not stir. Instead, allow the color to slowly mix into the water on its own.
3. Hold the cup up with a sheet of white paper behind it so it is easier for students to see the color moving and mixing in the water.

Expected results

The drops of food coloring will slowly move and mix into the water. Eventually all the water in the cup will be evenly colored.

Ask students:

How do your observations support the idea that water molecules are moving?

Help students understand that the drop of coloring mixes into the water because the water molecules move and push the color in all directions. The molecules of the food coloring themselves are also in motion.

Note: In chapter 5, students will learn that water molecules and coloring molecules are attracted to each other. These attractions also help explain the mixing of the color in the water.

EXPLAIN

5. Show an animation of the molecules in liquid water.



Show the molecular model animation *Particles of a Liquid*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson1#particles_of_a_liquid

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.

Point out that the molecules of a liquid are in motion but they are attracted to each other. That's why they move past each other but don't get very far apart from one another.



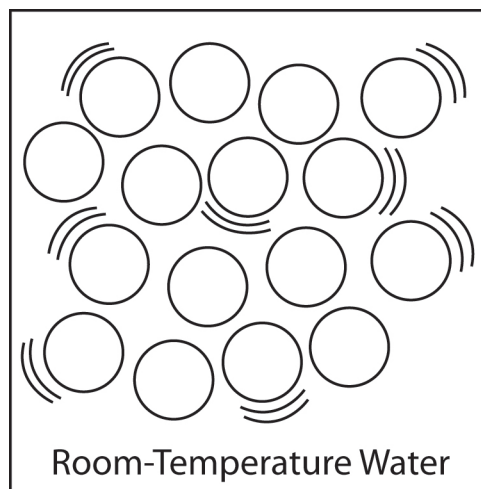
6. Have students draw their own model of water on the molecular level and complete the activity sheet.

Draw or project the illustration *Water Molecules*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson1#water_molecules

Explain to students that this is a model of water molecules. Point out that the molecules are not in any exact order but are near each other. They have little curved “motion lines” to show that the molecules are moving.

Have students draw a model of water on the molecular level on their activity sheet. They should use the model you have shown them to guide their own drawing.



Students' drawings should show that the molecules are:

- Randomly arranged
- Close together
- Moving



Be sure students realize that this model shows water molecules enormously bigger than they actually are. Not only are water molecules much smaller, they are also much more numerous. A single drop of water is made up of more than a billion trillion extremely tiny water molecules.

To give students an idea of how small and numerous water molecules are, you could tell students the following: In about 1 tablespoon of water, there are about 600 billion trillion water molecules. If you could count 1 million water molecules every second, it would take about 200 million centuries to count all the molecules in that tablespoon of water. Atoms and molecules are huge in number and incredibly small in size.

EXTEND

7. Show a video so that students can see an example that water molecules are attracted to one another.

Show a video of a water balloon popping in slow motion.

www.middleschoolchemistry.com/multimedia/chapter1/lesson1#water_balloon

Ask students:

- **Why do you think the water keeps its shape the moment the balloon is popped?**
Students should realize that water holds together pretty well because the water molecules are attracted to each other.
- **Imagine a drop of water hanging from your finger. How is this similar to the water staying together after the balloon is popped?**

This can also be explained by the fact that water molecules are very attracted to each other.

EXTRA EXTEND

3. If you have time, give students the opportunity to play games with drops of water.

Water Drops Unite!

Teacher Preparation

Print 2 “Water Drops Unite” sheets for each group.

Procedure

1. Tape a piece of wax paper over the “Water Drops Unite” sheet.
2. Place about 5 drops of water in each of the small circles around the outside.
3. As fast as you can, use your straw to drag each drop of water to the center. When all the drops are united in the center, you are done.
4. Challenge your partner to see who can unite all their water drops the fastest.



Race Drop Raceway

Teacher Preparation

Print 2 “Race Drop Raceway” sheets for each group. You and a partner can follow the directions below to race each other.

Procedure

1. Tape the “Race Drop Raceway” sheet onto a piece of cardboard to give it support.
2. Tape a piece of wax paper over the “Race Drop Raceway” sheet.
3. Place 2–4 drops of water together to make one larger drop at the “Start.”
4. As fast as you can, tilt the cardboard and guide your race drop around the track to the “Finish.” Try not to touch the edge of the track. The first to finish is the winner.

Activity Sheet
Chapter 1, Lesson 1
Molecules Matter

Name: _____

Date: _____

In the activity below, you will investigate some of the characteristics of water. You will also begin to model and explain, on the molecular level, why water acts the way it does.

ACTIVITY

Question to investigate

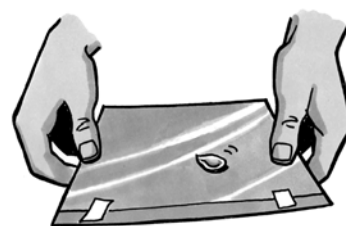
Does water hold together well or come apart easily?

Materials for each group

- Water in small cup
- Dropper
- 2 popsicle sticks
- 2 index cards covered with wax paper

Procedure

1. Use a dropper to gently squeeze out one drop of water but try not to let the drop fall completely out of the dropper. See how far you can make the drop hang off the end of the dropper without the drop falling.
2. Place 4 or 5 drops of water together on the wax paper to make a medium-size drop.
3. Gently tilt the wax paper in different directions so that the drop moves.
4. Use a popsicle stick to slowly move your drop around the wax paper. Try using your popsicle stick to separate your drop into two.
5. Use your popsicle stick to move the two drops near each other. Then move one drop so that the two drops touch.



WHAT DID YOU OBSERVE?

1. When you squeezed the drop of water out of the dropper, did the water break apart did it hold together?

2. When you were pulling the drop around the wax paper, did the water seem to hold together or come apart easily?

3. When you tried to split your drop, did the drop separate easily?

4. Was it easy or difficult to make the drops come together?

DEMONSTRATION

5. Your teacher placed a drop of food coloring in a cup of water. The color slowly mixed into the water without being stirred. What does this tell you about water molecules?

EXPLAIN IT WITH ATOMS & MOLECULES

You saw an animated molecular model of water. Now you will draw your own molecular model.

6. Using circles and motion lines to represent water molecules, draw a model of water on the molecular level. Be sure to show that water molecules are:

- Randomly arranged.
- Close together because they attract each other.
- Moving



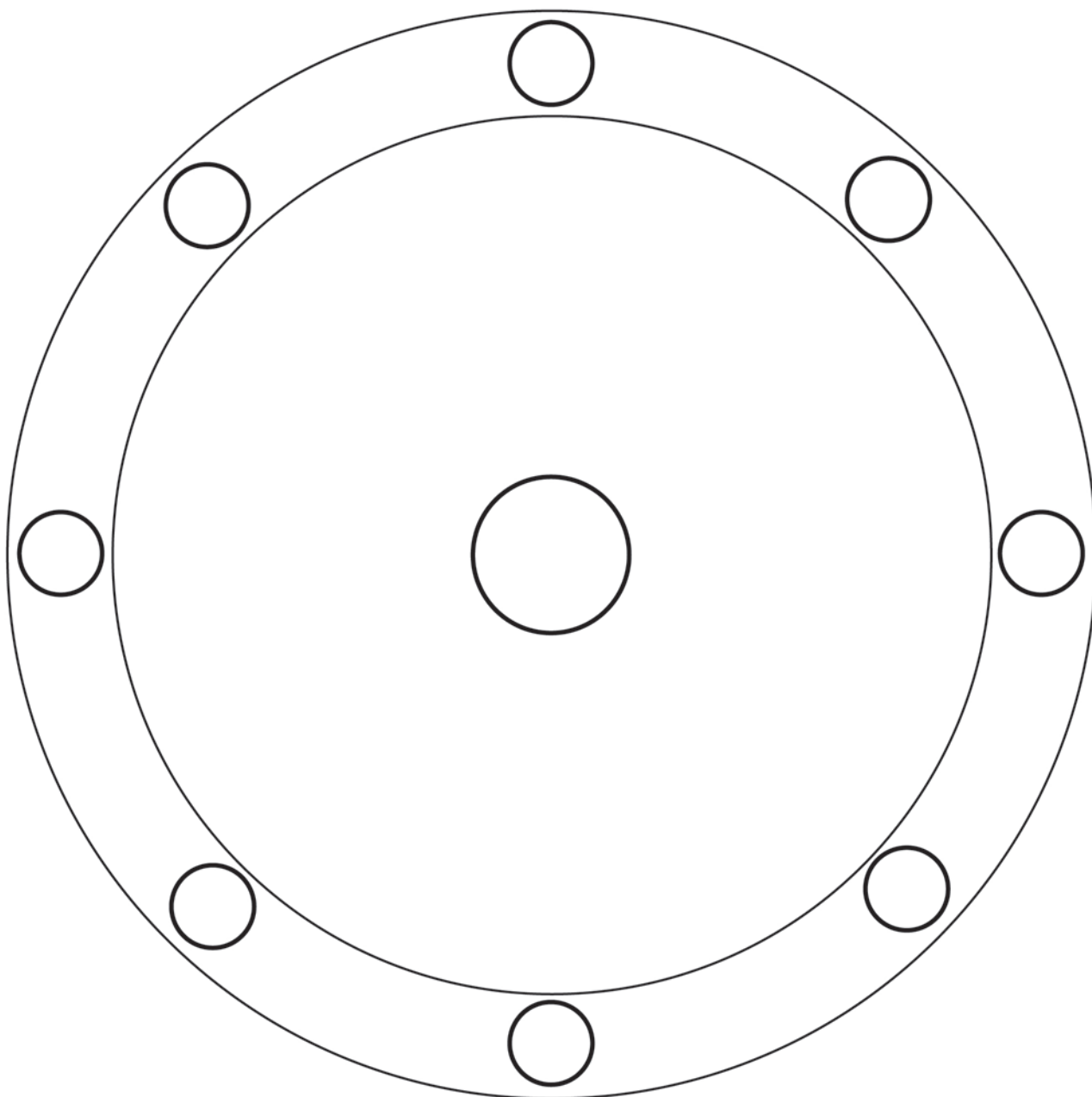
7. What is it about water molecules that helps explain why the water drops were difficult to split apart but easy to join together?

TAKE IT FURTHER

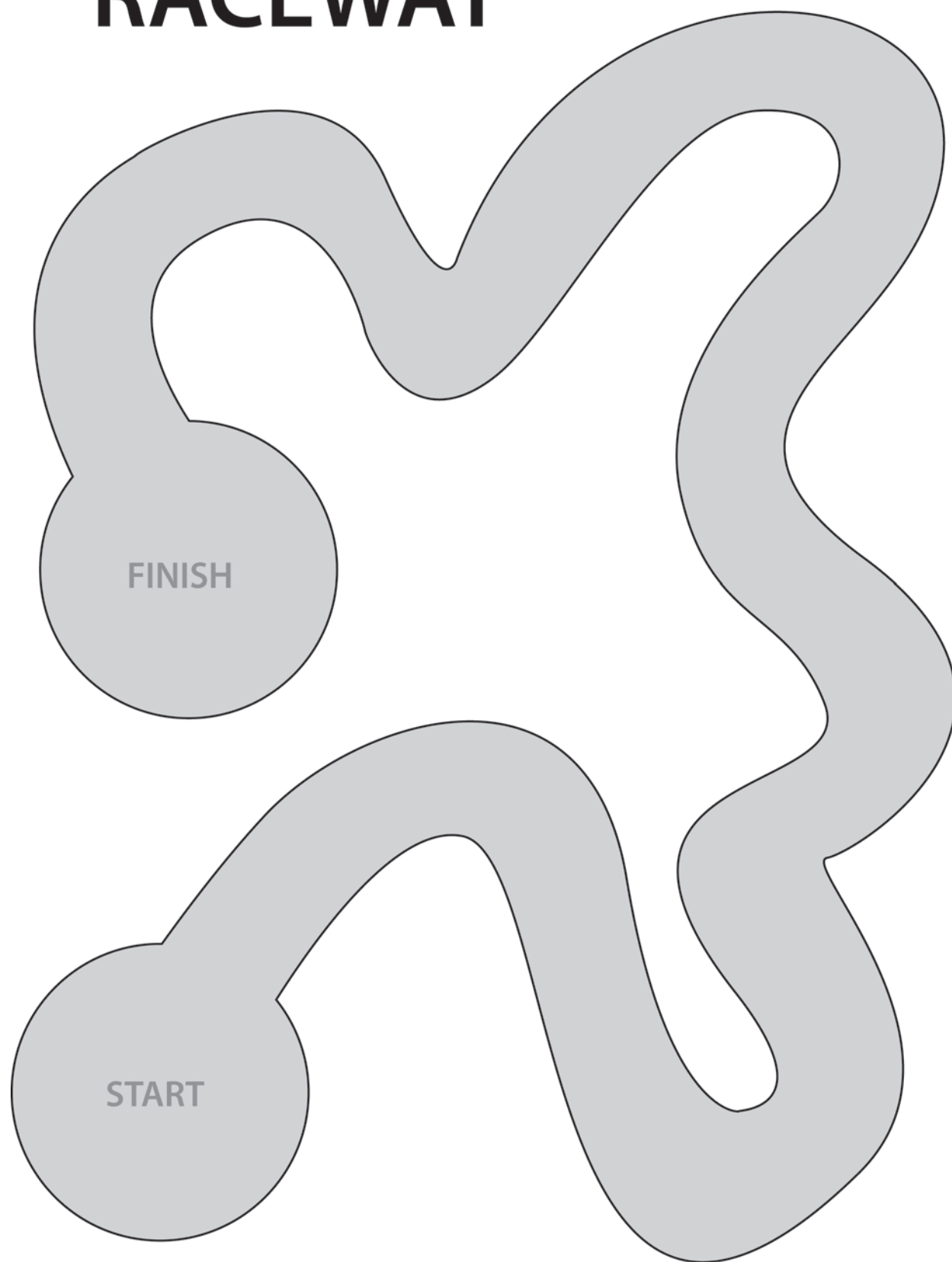
In the video of the water balloon, you saw what happens in slow motion when a water balloon is popped. Surprisingly, there is a moment when the water hangs in the air in a balloon-shape, after the balloon has been popped.

8. Why do you think the water keeps its shape the moment the balloon is popped?
9. Imagine a drop of water hanging from your finger. How is this similar to the water staying together after the balloon is popped?

WATER DROPS **UNITE!**



RACE DROP RACEWAY



Chapter 1, Lesson 2: Molecules in Motion

Key Concepts

- Heating a liquid increases the speed of the molecules.
- An increase in the speed of the molecules competes with the attraction between molecules and causes molecules to move a little further apart.
- Cooling a liquid decreases the speed of the molecules.
- A decrease in the speed of the molecules allows the attractions between molecules to bring them a little closer together.

Summary

Students add food coloring to hot and cold water to see whether heating or cooling affects the speed of water molecules. Students watch molecular model animations to see the effect of heating and cooling on the molecules of a liquid. Students will also draw their own molecular model.

Objective

Students will be able to explain, on the molecular level, that heating and cooling affect molecular motion.

Evaluation

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles.

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

ENGAGE

- 1. Ask students to help you design an experiment to see if the speed of water molecules is different in hot water compared to cold water.**

Ask students questions such as the following:

- **Is the speed of water molecules 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 to find 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 that 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 the 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. Temperature should be the only variable. This way, if we notice something different between the two samples of water, we will know that the difference in temperature is causing it.

Give each student an activity sheet.

Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* 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.



EXPLORE

2. **Do an activity 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?

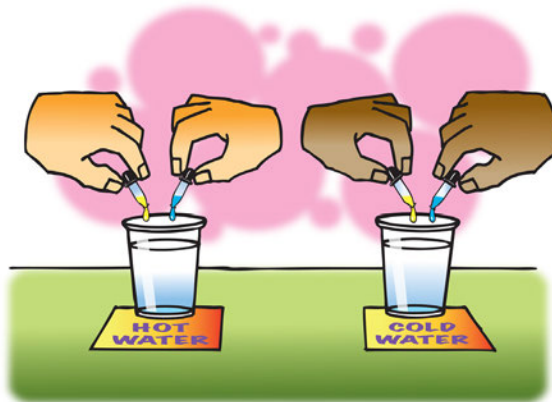
Teacher preparation

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 about 6 cups of tap water to make it sufficiently cold.
4. Pour about $\frac{3}{4}$ cup of cold water (no ice) into a cup for each group.
5. Pour about $\frac{3}{4}$ 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 as you watch them 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.



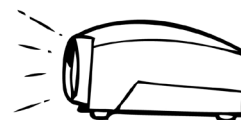
- Describe what the colors looked like and how they moved and mixed in the cold water.
- Describe what the colors looked like and how they moved and mixed in the hot water.
- What does the speed of the mixing colors tell you about the speed of the molecules in hot and cold water?

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 colors mix faster in the hot water because the molecules of both the water and food coloring move faster in hot water than they do in cold water.

EXPLAIN

4. Show an animation of water molecules at different temperatures.



Show the molecular model animation *Heating and Cooling a Liquid*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson2#heating_and_cooling

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 quickly 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.

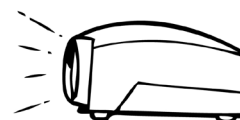


Have students fill in the blank with the word *increases* or *decreases* on their activity sheet as you read each sentence.

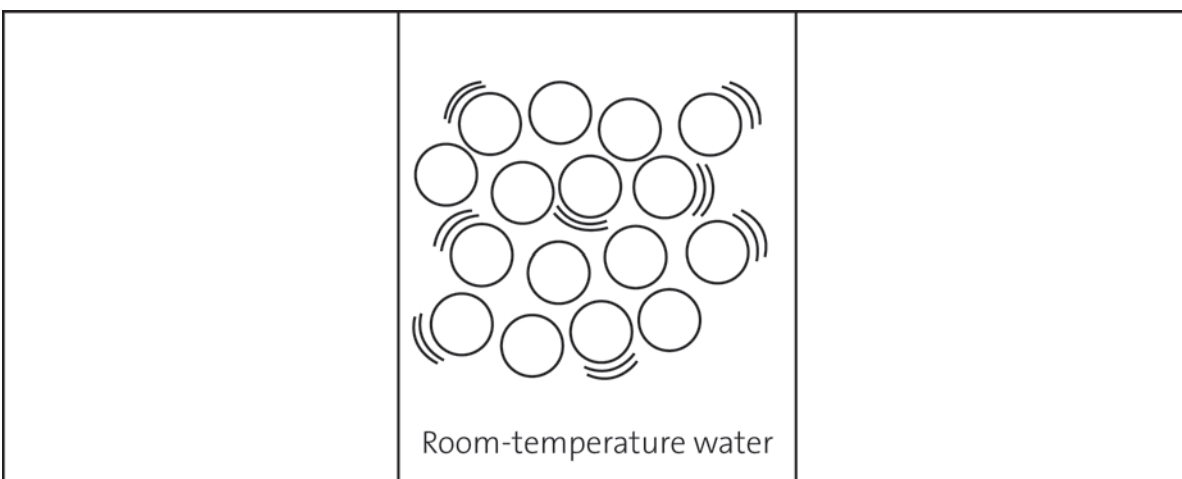
- Heating a substance *increases* molecular motion.
- Cooling a substance *decreases* molecular motion.
- As molecular motion increases, the space between molecules *increases*.
- As molecular motion decreases, the space between molecules *decreases*.

Project the image *Water Molecules at Different Temperatures*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson2#water_molecules_at_different_temperatures



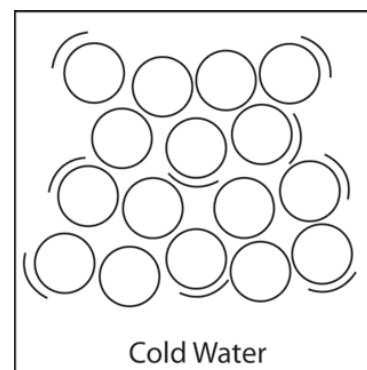
Have students refer to the drawing of room-temperature water on their activity sheet and discuss how they should represent the molecules in cold and hot water.



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.



Hot water

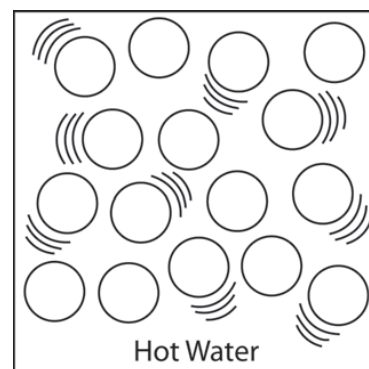
Ask students:

- **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.



EXTEND

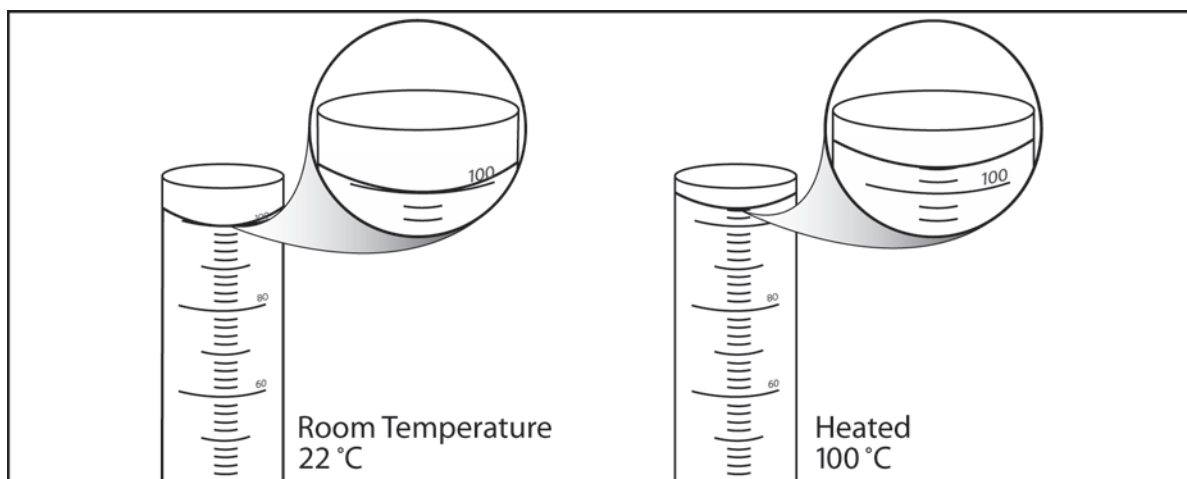
6. **Have students explain why hot water takes up more space than room-temperature water.**

Have students read and discuss the *Take It Further* question on the activity sheet. After the class discussion, have students write their own response to the following question in the space provided on the activity sheet.



- **Let's say that you measure exactly 100 milliliters of water in a graduated cylinder. You heat the water to 100 °C and notice that the volume increases to 104 milliliters. Using what you know about the attractions between water molecules and the way heating affects molecular motion, explain why the volume of water in the cylinder increases when it is heated.**

Students should realize that the molecules in hot water move slightly further apart, accounting for the increased volume.



Name _____

Name _____

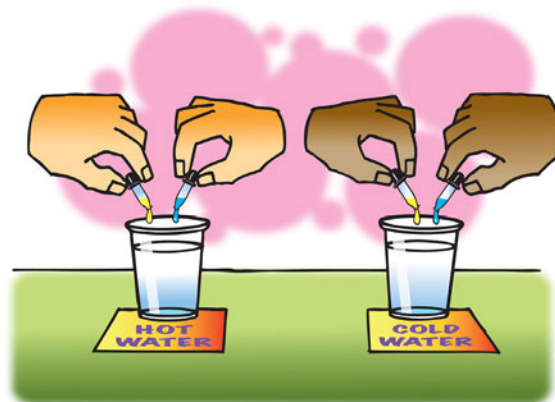
ACTIVITY

Question to investigate

Is the speed of water molecules different in hot and cold water?

Materials for each group

- Hot water in a clear plastic cup
- Cold water in a clear plastic cup
- Food coloring (yellow and blue)
- 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 as you watch them for a couple of minutes.

WHAT DID YOU OBSERVE?

1. Describe what the colors looked like and how they moved and mixed in the cold water.
2. Describe what the colors looked like and how they moved and mixed in the hot water.
3. What does the speed of the mixing colors tell you about the speed of the molecules in hot and cold water?

4. There were several variables in this experiment:

- Amount of water in each cup
- Type of cup used
- Number of drops of food coloring
- When the coloring was added to the water

Pick one of these variables and explain why you made sure it was kept the same in the two cups.

EXPLAIN IT WITH ATOMS & MOLECULES

You saw an animation of water molecules being heated and cooled. Now you can draw your own molecular model.

5. Based on your observations and the animations, fill in the blanks with the words *increases* or *decreases*.

Heating a substance _____ molecular motion.

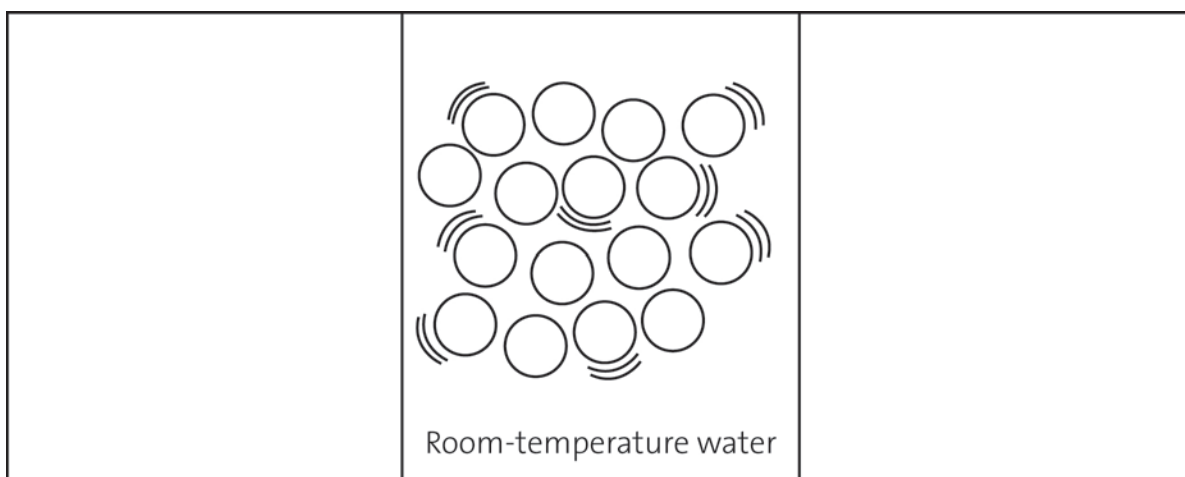
Cooling a substance _____ molecular motion.

As molecular motion increases, the space between molecules _____.

As molecular motion decreases, the space between molecules _____.

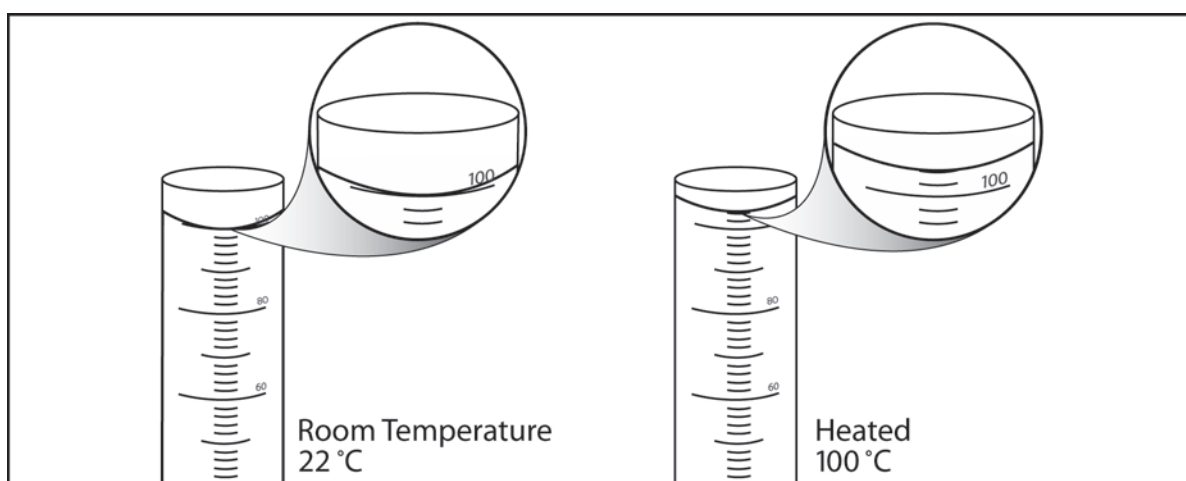
6. Using circles to represent water molecules, draw a model of the molecules in cold and hot water.

- Use motion lines to show the speed of the molecules.
- Consider the space between molecules in each temperature of water.



TAKE IT FURTHER

Let's say that you measure exactly 100 milliliters of water in a graduated cylinder. You heat the water to 100 °C and notice that the volume increases to 104 milliliters.



- Using what you know about the attractions between water molecules and the way heat affects molecular motion, explain why the volume of water in the cylinder increases when it is heated.

Chapter 1, Lesson 3: The Ups and Downs of Thermometers

Key Concepts

- The way a thermometer works is an example of heating and cooling a liquid.
- When heated, the molecules of the liquid in the thermometer move faster, causing them to get a little farther apart. This results in movement up the thermometer.
- When cooled, the molecules of the liquid in the thermometer move slower, causing them to get a little closer together. This results in movement down the thermometer.

Summary

Students will look closely at the parts of a thermometer. After placing a thermometer in hot and cold water, students will look at molecular model animations of the liquid in a thermometer. Students will then draw a model of the molecules of a thermometer after it has been placed in hot and then cold water.

Objective

Students will be able to describe, on the molecular level, why the liquid in a thermometer goes up when it is heated and down when it is cooled.

Evaluation

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

- Be sure you and the students wear properly fitting goggles.
- Students should use care when handling hot tap water.
- When using isopropyl alcohol, read and follow all warnings on the label. Isopropyl alcohol is flammable. Keep it away from any flames or spark sources.

Materials for Each Group

- Student thermometer
- Magnifier
- Cold water
- Hot water (about 50 °C)

Notes about the materials

Student thermometers are available from Sargent Welch (WL5679), Flinn Scientific (AP5406) and other suppliers.

ENGAGE

1. Find out what students know about thermometers.

Hold up an alcohol thermometer and ask students:

- **Why do you think the liquid in a thermometer moves up and down when it is heated and cooled?**

Students should realize that the movement of the liquid in a thermometer is related to the motion of the molecules of the liquid when they are heated and cooled.

Remind students that molecules move faster and a little further apart when they are heated. Molecules also move slower and a little closer together when they are cooled.

Tell students that they will apply their understanding of what happens when liquids are heated and cooled to explain how a thermometer works.

Give each student an activity sheet.

Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* 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.



EXPLORE

2. Do an activity to investigate what makes the liquid in a thermometer go up and down.

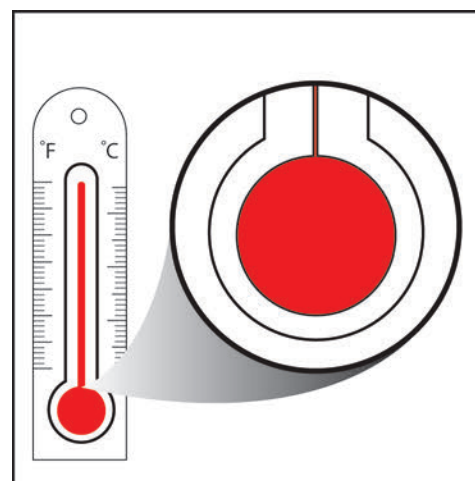


Question to investigate

What makes the liquid in a thermometer go up and down?

Materials for each group

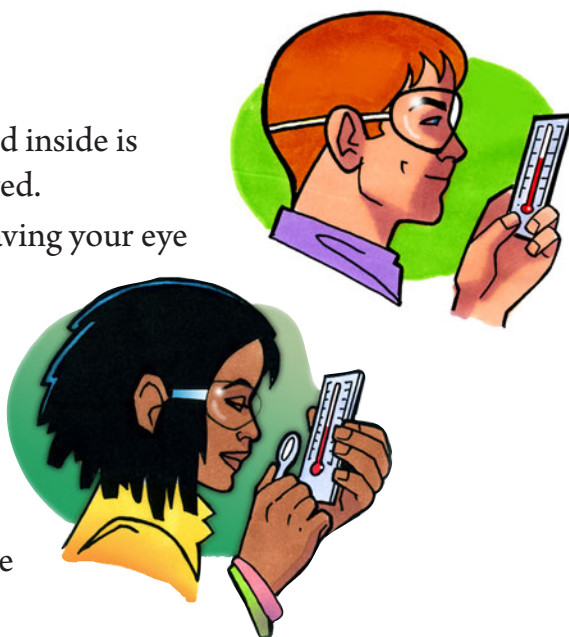
- Student thermometer
- Magnifier
- Cold water
- Hot water (about 50 °C)



Procedure

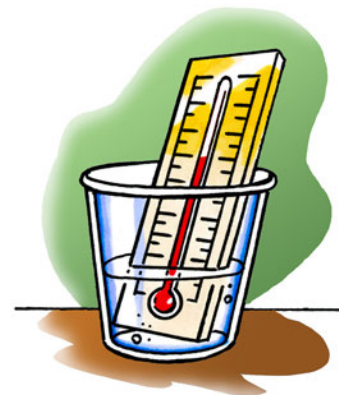
A. Look closely at the parts of a thermometer.

1. Look closely at your thermometer. The liquid inside is probably a type of alcohol that's been dyed red.
2. Practice reading the temperature in $^{\circ}\text{C}$ by having your eye at the same level as the top of the red liquid. What is the temperature?
3. Use a magnifier to look closely at the thermometer from the front and from the side. Look at the bulb and the thin tube that contains the red liquid.
4. Put your thumb or finger on the bulb and see if the red liquid moves in the thin tube.



B. Observe the red liquid in the thermometer when it is heated and cooled.

5. Place the thermometer in hot water and watch the red liquid. Keep it in the hot water until the liquid stops moving. Record the temperature in $^{\circ}\text{C}$.
6. Now put the thermometer in cold water. Keep it in the cold water until the liquid stops moving. Record the temperature in $^{\circ}\text{C}$.



Expected results

The red liquid goes up in hot water and down in cold water. Students will have an opportunity to relate these observations to an explanation, on the molecular level, of why the liquid moves the way it does.

If you have time, you can have students pick a temperature somewhere between the temperature of cold water and hot water and then attempt to combine an amount of hot and cold water to achieve that temperature in one try. They can see how close they can get.

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.

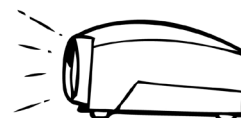


1. Based on what you know about the way molecules move in hot liquids, explain why the liquid in the thermometer goes up when heated.
2. Based on what you know about the way molecules move in cold liquids, explain why the liquid in the thermometer goes down when cooled.
3. Why do you think the tube that contains the red liquid is so thin?
4. What do you think is the purpose of the larger outer tube?

When heated, the molecules of the red liquid inside the thermometer move faster. This movement competes with the attractions the molecules have for each other and causes the molecules to spread a little further apart. They have nowhere to go other than up the tube. When the thermometer is placed in cold water, the molecules slow down and their attractions bring them a little closer together bringing them down the tube. The red liquid is contained in a very thin tube so that a small difference in the volume of the liquid will be noticeable. The large outer tube has two purposes—to protect the fragile inner tube and act as a magnifier to help you better see the red liquid.

EXPLAIN

4. Show an animation of the molecules of liquid in a thermometer as they are heated and cooled.



Note: Alcohol molecules are composed of different atoms, but in the model shown in the animation the molecules are represented as simple red spheres.

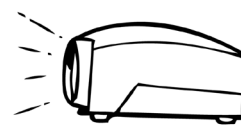
Show the molecular model animation *Heating and Cooling a Thermometer*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson3#heating_and_cooling_a_thermometer

Point out that when the thermometer is heated, the molecules move faster, get slightly further apart, and move up the tube. When the thermometer is cooled, the molecules move more slowly, get closer together, and move down the tube. Help students realize that the attractions the molecules in the thermometer have for each other remain the same whether the thermometer is heated or cooled. The difference is that when heated, the molecules are moving so fast that the movement competes with the attractions, causing the molecules to move further apart and up the tube. When cooled, the movement of the molecules is slower and does not compete as much with the attractions the molecules have for one another. This is why the molecules in the thermometer move closer together and down the tube.

Ask students:

- **The animation shows that the molecules spread out slightly when heated. Do you think the thermometer would work as well if the tube of red liquid were wider?**



The molecules spread out in all directions when heated. If the tube were wide, the molecules would be free to spread out sideways as well as up. In the thin tube, the molecules can't move very far sideways, so they go up. This causes a greater difference in the height of the liquid, which is easier to see.

3. Have students draw a molecular model to represent the molecules of the liquid in a thermometer.

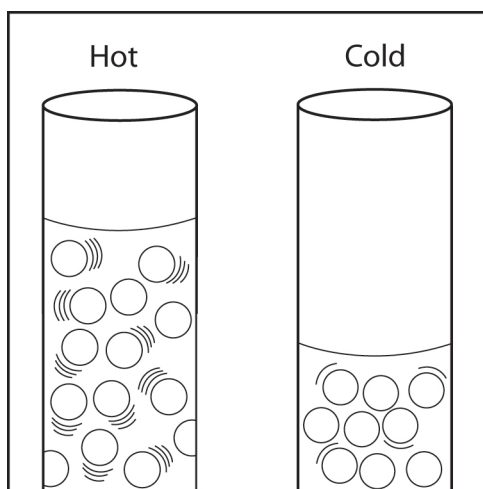
Project the image *Molecules in a Thermometer*.

www.middleschoolchemistry.com/multimedia/chapter3/lesson1#molecules_in_a_thermometer

In the drawing, lines have been added to indicate the level of the liquid in each tube. In reality, there is no line. The “line” is made up of molecules. Students should draw circles representing molecules all the way up to the line drawn in each tube.



Have students use the projected illustration as a guide as they draw a model of the molecules in a hot and cold thermometer on their activity sheet.



The *Hot Thermometer* illustration should show random circles with more motion lines. The circles should be a little further apart than in the cold thermometer.

The *Cold Thermometer* should show random circles with fewer motion lines. The circles should be a little closer together than the circles in the hot thermometer.

EXTEND

4. Discuss with students why thermometers with different liquids in them rise to different heights even at the same temperature.

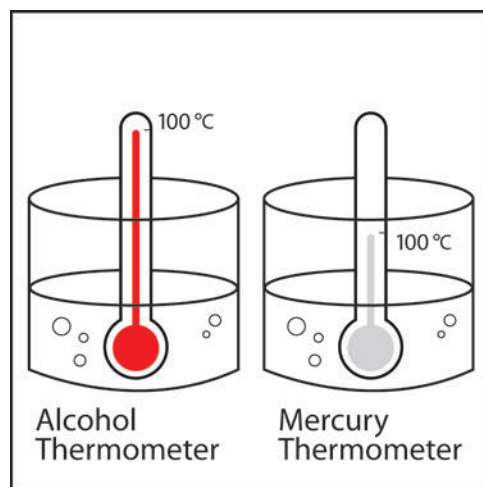
Project the image *Different Thermometers Same Temperature*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson3#different_thermometers_same_temperature

Tell students that this picture shows two thermometers that are identical in every way, except one has alcohol and the other has mercury inside. Point out that both thermometers are placed in hot water that is 100°C . The levels of the alcohol and mercury are shown.

Ask students:

- How can the liquids in the thermometers be at different levels even though they are in water that is the same temperature?



Hint: Alcohol and mercury are both liquids but are made of different atoms and molecules. Use what you know about the motion and attractions the particles in a liquid have for one another to explain why the levels of alcohol and mercury in the thermometers are different.



The main reason why the level of liquid in each thermometer is different is that they are different substances with different properties. The molecules that make up the alcohol have different attractions for each other than the atoms that make up the mercury. Therefore, heating and cooling them are going to make them move different distances up or down the tube.

After the class discussion, have students write their own response to the question about the two different thermometers on the activity sheet.

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ACTIVITY

Question to investigate

What makes the liquid in a thermometer go up and down?

Materials for each group

Student thermometer

Magnifier

Cold water

Hot water (about 50 °C)

Procedure

A. Look closely at the parts of the thermometer.

1. Look closely at your thermometer. The liquid inside is probably a type of alcohol that's been dyed red.
2. Read the temperature in °C by having your eye on the same level as the top of the red liquid. What is the temperature?
3. Use a magnifier to look closely at the thermometer from the front and from the side. Look at the bulb and the thin tube that contain the red liquid.
4. Put your thumb or finger on the red bulb and see if the red liquid moves in the thin tube.



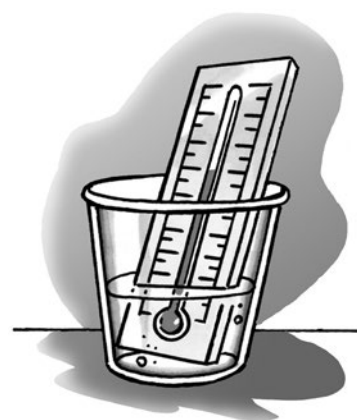
B. Observe the red liquid in the thermometer when it is heated and cooled.

1. Place the thermometer in hot water and watch the red liquid. Keep it in the hot water until the liquid stops moving.

Record the temperature in °C. _____

2. Now put the thermometer in cold water. Keep it in the cold water until the liquid stops moving.

Record the temperature in °C. _____



WHAT DID YOU OBSERVE?

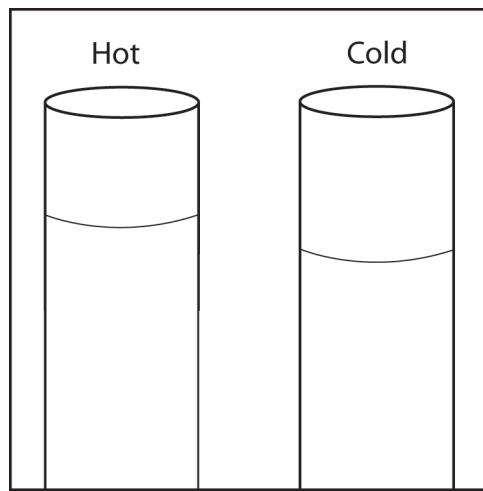
1. Based on what you know about the way molecules move in hot liquids, explain why the liquid in the thermometer goes up when heated.
2. Based on what you know about the way molecules move in cold liquids, explain why the liquid in the thermometer goes down when cooled.
3. Why do you think the tube that contains the red liquid is so thin?
4. What do you think is the purpose of the larger outer tube?

EXPLAIN IT WITH ATOMS & MOLECULES

You saw an animated molecular model of a thermometer at different temperatures. Now you will draw your own model.

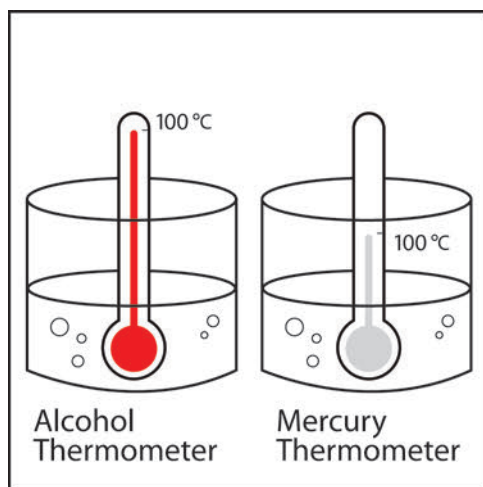
The drawing shows two close-ups of a thin tube in a thermometer like the one you used. One picture represents the thermometer in hot water, while the other is the thermometer in cold water.

5. Based on what you know about the motion of molecules in a liquid and what you saw in the animations, draw circles to represent alcohol molecules in the liquid in the thermometer. Try to show the difference in distance between the molecules when the liquid is hot and cold. Use motion lines to represent their movement (fast or slow).



TAKE IT FURTHER

6. Imagine that you have two thermometers that are identical in every way, except one has alcohol and the other has mercury inside. Each thermometer is placed in hot water that is $100\text{ }^{\circ}\text{C}$. The levels of the alcohol and mercury are shown in the picture.



Why do you think the liquids in the thermometers are at different levels even though they are in water that is the same temperature?

Hint: Alcohol and mercury are both liquids but are made of different atoms and molecules. Use what you know about the motion and attractions the particles in a liquid have for one another to explain why the levels of alcohol and mercury in the thermometers are different.

Chapter 1, Lesson 4: Moving Molecules in a Solid

Key Concepts

- In a solid, the atoms are very attracted to one another. The atoms vibrate but stay in fixed positions because of their strong attractions for one another.
- Heating a solid increases the motion of the atoms.
- An increase in the motion of the atoms competes with the attraction between atoms and causes them to move a little further apart.
- Cooling a solid decreases the motion of the atoms.
- A decrease in the motion of the atoms allows the attractions between atoms to bring them a little close together.

Summary

Students will see a demonstration with a metal ball and ring showing that heat causes atoms to spread a little further apart. They will also see that cooling a solid causes the atoms to get a little closer together. The same rules they discovered about liquids also apply to solids.

Objective

Based on their observations students will describe, on the molecular level, how heating and cooling affect the motion of atoms in a solid.

Evaluation

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

Be sure you and the students wear properly fitting goggles.

Materials for the Demonstration

- Ball and ring designed specifically for this demonstration]
- Bunsen burner for heating the ball
- Room-temperature water (to cool the ball)

Notes about the materials

The metal ball and ring is available from Sargent Welch (WL1661-10) or Flynn Scientific (AP9031) or other suppliers.

About this Lesson

The solid explored in this lesson is a metal. Metal is composed of individual atoms instead of molecules like in the water and alcohol students learned about in Lessons 1–3. Although atoms and molecules are different, we will represent atoms the same way we represented molecules, using a circle or sphere. This simple representation will help students focus on the motion and position of the particles when they are heated and cooled.

ENGAGE

1. Review what students have discovered about molecules in a liquid and discuss whether these same ideas might apply to solids, too.

Ask students:

- **What do you know about the molecules in a liquid?**

Be sure students understand that the molecules in a liquid are attracted to each other but are able to move past each other.

- **How does heating or cooling affect the speed of the molecules and the distance between them?**

Heating speeds up the motion of molecules and cooling slows them down. We've also seen that speeding the molecules up makes them move a little further apart and slowing them down allows them to move a little closer together.

Ask students if these statements also apply to solids:

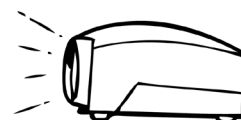
- **Do you think the atoms in a solid are attracted to each other?**

Students will probably realize that the atoms of a solid are attracted to each other. Explain that this is how a solid stays together.

- **Do you think heating or cooling a solid might affect the motion of the atoms?**

Students should realize that if you heat a solid, the atoms or molecules move faster and move further apart. If you cool a solid, the molecules move more slowly and move a little closer together.

2. Show an animation to help students compare atoms and molecules in solids and liquids.



Explain that the little balls represent the particles of a solid, in this case the atoms in a metal. Although atoms and molecules are different, this same simple model of balls is used for both. 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. Tell students that they should focus on the motion of the molecules, how they interact, and their distance from one another.

Show the molecular model animation *Particles of a Solid*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson4#particles_of_a_solid

Point out the following about solids:

- The particles (atoms or molecules) are attracted to each other.
- The particles (atoms or molecules) vibrate but do not move past one another.
- The solid retains its shape.

Show the molecular model animation *Comparing Solid and Liquid*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson4#comparing_solid_and_liquid

Click on both tabs and make sure students notice the differences in the movement of the atoms and molecules.

- The atoms in a solid are so attracted to each other that they vibrate and don't move past each other.
- The molecules of a liquid are attracted to each other, but move more freely and past one another.



Give each student an activity sheet.

Students will record their observations and answer questions about the animation on the activity sheet. The *Explain It with Atoms & Molecules* 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.

EXPLORE

3. Do a demonstration to show that solid metal expands when it is heated and contracts when cooled.

It is harder to show that the particles of a solid move faster when heated than it is to show the same thing with a liquid like in Lesson 2. But you can do it if you have a special ball and ring apparatus that shows the expansion of a metal when heated. This inexpensive device, available through science education equipment companies, consists of a rod with a metal ball on the end and another rod with a metal ring. At room-temperature, the ball just barely fits through the ring. But when the ball is heated sufficiently, it will not pass through the ring. If you do not have this equipment, you can show students a video of this demonstration titled *Heating and Cooling a Metal Ball*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson4#heating_cooling_metal_ball

Question to investigate

How do heating and cooling affect a solid?



Materials for the presenter

- Ball and ring designed specifically for this demonstration
- Bunsen burner for heating the ball
- Room-temperature water (to cool the ball)

Procedure

A. Heating the metal ball

1. Hold the ball in one hand and the ring in the other. Show students how the ball fits through the ring.
2. Place the metal ball in the flame of a Bunsen burner for about 1–2 minutes.
3. Try to push the ball through the metal ring again.



Expected results

The ball will not fit through the ring.

Ask students:

- **Why won't the ball fit through the ring?**

Students should infer that the speed of the atoms in the metal ball has increased. This increased motion competes with the attractions the atoms have for each other, causing the atoms to move slightly further apart. This is why the heated ball is too big to fit through the ring.



When students see that the ball expands, they may wonder if the atoms themselves expanded. Tell students that the atoms do not expand. Instead, the atoms in a solid follow the same rules as the molecules in a liquid. Heating increases molecular motion, causing the atoms to spread a little further apart.

B. Cooling the metal ball

Ask students:

- **What could we do to the metal ball to make it fit through the ring again?**

Students should suggest cooling the ball.

4. Dip the ball in room-temperature water.
5. Push the ball through the metal ring.



Expected results

The ball will fit through the ring.

Ask students:

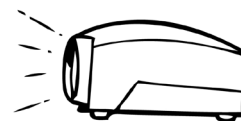
- **Why does the ball fit through the ring now?**

Students should infer that the atoms slow down enough so that their attractions pull them closer together, making the ball smaller so that it can fit through the ring.



EXPLAIN

4. Show an animation and explain what happened to the atoms in the metal ball as it was heated and cooled.



Show the molecular model animation *Heating and Cooling a Solid*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson4#heating_and_cooling_a_solid

Point out that when metal is heated, the atoms move faster and move slightly further apart. This makes the heated ball expand, which prevents it from passing through the ring.

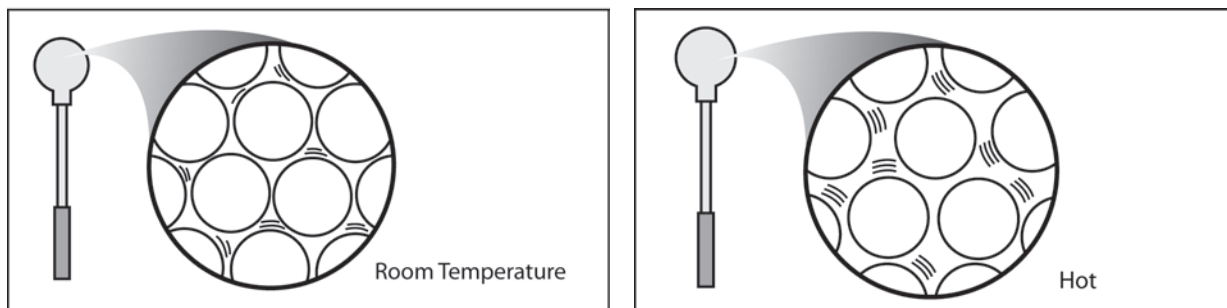
Point out that when the metal is cooled, the atoms move slower and move slightly closer together. This makes the cooled metal ball get slightly smaller so that it fits through the ring again.



Give students time to complete the questions and drawings on the activity sheet about heating and cooling the metal ball.

Project the image *Molecules in a Room-Temperature and Hot Metal Ball*.

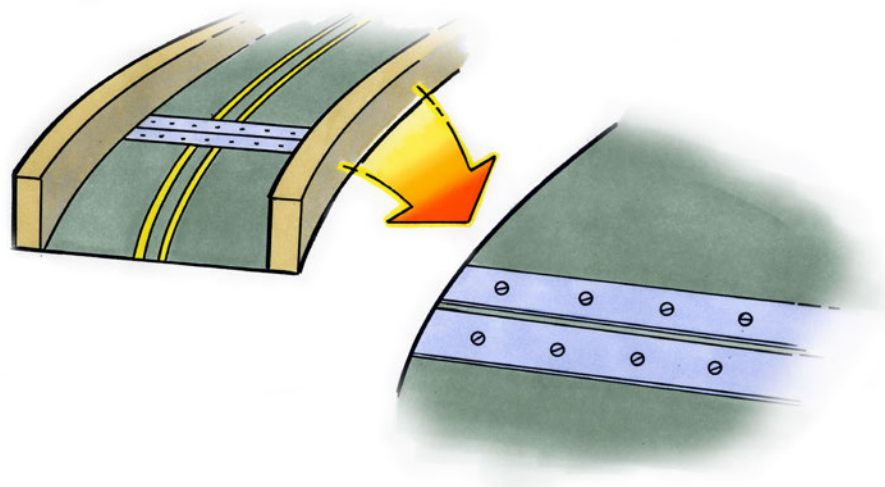
Help students draw circles to represent the atoms in the ball at room-temperature and after it is heated. Have students write captions describing the speed and distance of the atoms in each picture.



EXTEND

5. Have students apply what they have learned about heating and cooling solids to explain why bridges have flexible connections.

Show students the picture of the flexible connection in the road on a bridge. Explain that the surface of the bridge gets colder in winter and hotter in summer than the road on either end of the bridge. This is because the bridge is completely surrounded by cold air in the winter and by hot air in the summer. It is not insulated by the ground beneath it.



Ask students:

- **Knowing what you do about how solids act when they are heated and cooled, why do you think they put flexible connections in the surface of a bridge?**



Students should realize that if the bridge is hotter than the land around it, it should be able to expand a bit without breaking. If it is colder than the land around it, it should be able to contract a bit without breaking.

After the class discussion, have students write their own response to the question about flexible bridge connections on the activity sheet.

EXPLAIN IT WITH ATOMS & MOLECULES

After you watch the molecular model animations of liquids and solids, answer the questions below.

1. How is the motion of the atoms in solid metal different from the motion of the molecules in liquid water?
2. What is it about atoms and molecules in liquids and solids that keep them close to one another even though they are moving?

DEMONSTRATION

3. At room-temperature the metal ball fit through the ring. What happened when your teacher tried to push the heated ball through the ring?
4. What happened to the atoms in the heated metal ball so that it didn't fit through the ring?



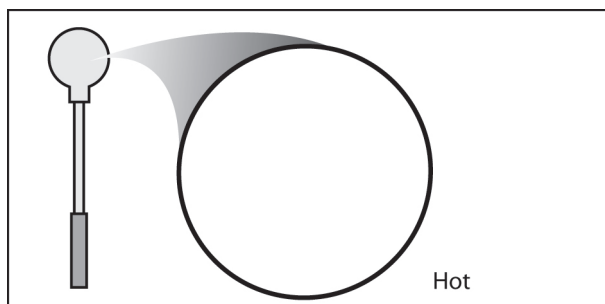
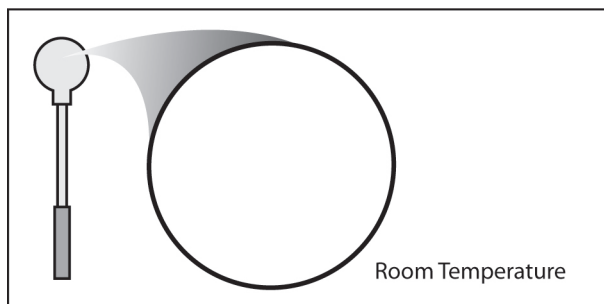
5. After the ball was cooled by putting it in the water, why do you think it fit through the ring again?



EXPLAIN IT WITH ATOMS & MOLECULES

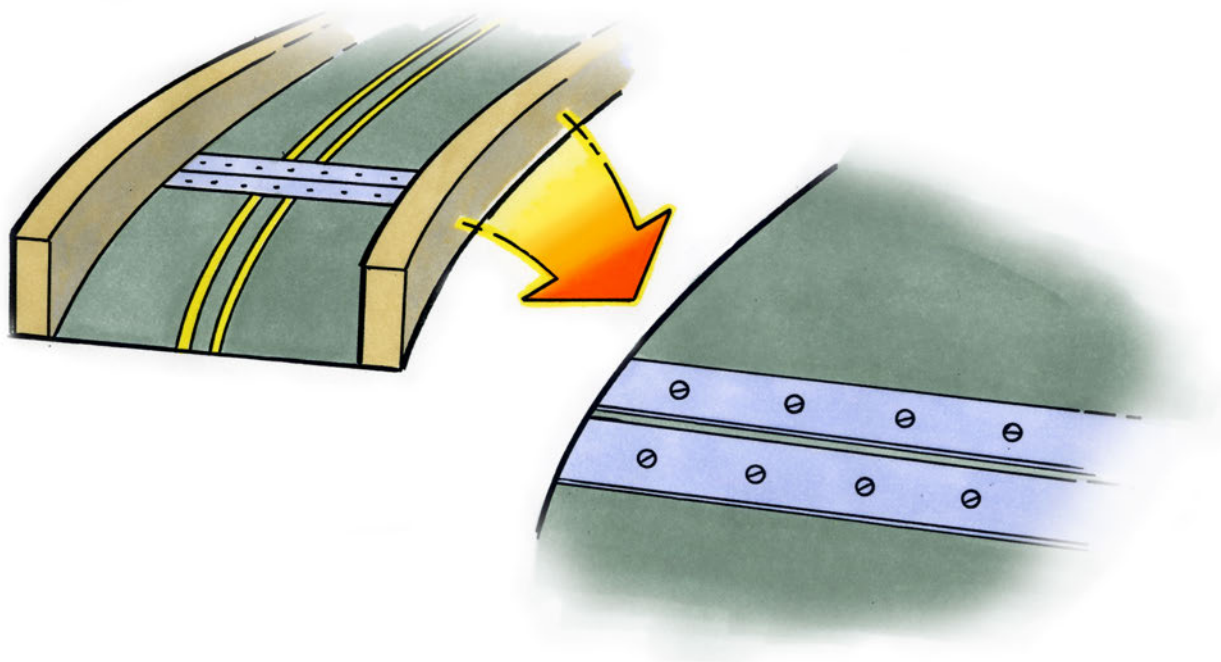
You saw in the animation that atoms in a solid move faster and get slightly further apart when heated. You also saw that they slow down and get slightly closer together when cooled. Use this information to make your own drawing on the molecular level of the metal ball.

6. Draw a model of the atoms in the metal ball at room-temperature and after it has been heated. Use circles and motion lines to show the speed and spacing of the atoms in the room-temperature ball. Include captions like “atoms faster and further apart” or “atoms slower and closer together” to describe your drawings



TAKE IT FURTHER

Look at the picture of the road of a bridge. The road on a bridge gets colder in the winter and hotter in the summer than the road leading to it and away from it. Many bridges have a flexible connection like the one shown in the picture.



7. Knowing what you do about how solids act when they are heated and cooled, why do you think they put flexible connections in the road on a bridge?

Chapter 1, Lesson 5: Air, It's Really There

Key Concepts

- In a gas, the particles (atoms and molecules) have weak attractions for one another. They are able to move freely past each other with little interaction between them.
- The particles of a gas are much more spread out and move more independently compared to the particles of liquids and solids.
- Whether a substance is a solid, liquid, or gas at a certain temperature depends on the balance between the motion of the particles at that temperature and how strong their attractions are for one another.
- Heating a gas increases the speed of its atoms or molecules.
- Cooling a gas decreases the speed of its atoms or molecules.

Summary

Students compare the mass of a basketball when it is deflated and after it has been inflated. The inflated ball has the greater mass, so students can conclude that gas is matter because it has mass and takes up space. Then students consider how heating and cooling affect molecular motion in gases. They dip the mouth of a bottle in detergent solution and observe a bubble growing and shrinking when the bottle is warmed and cooled. Students will learn that the attractions between the particles of gases are weak compared to the attractions between the particles of liquids or solids.

Objective

Students will be able to describe gas as matter. They will also be able to describe, on the molecular level, the effect of heating and cooling on the motion of molecules of a gas.

Evaluation

The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan. The activity sheets are formative assessments of student progress and understanding. A more formal summative assessment is included at the end of each chapter.

Safety

- Be sure you and the students wear properly fitting goggles.
- Students should use care when handling hot tap water.

Materials for Each Group

- 2 clear plastic cups
- 8-oz plastic bottle
- Detergent solution in a cup
- Hot water (about 50 °C)
- Cold water

Materials for the Demonstration

- Basketball, very deflated
- Balance that measures in grams
- Pump
- Can of compressed gas (available at any office supply store)

ENGAGE

1. Discuss with students whether they think gas is matter.

Ask students about gases:

- **Are gases, such as the gases in air, matter?**

Students may have questions about whether or not gases are matter. They may also have only a very vague sense of what gases are at all. After students reply, explain that the air around them is made up of some different gases—nitrogen, oxygen, carbon dioxide, water vapor, and very small amounts of some others. Tell students that gases are made of molecules but that the molecules are much further apart than the molecules in liquids or solids. Since the molecules of a gas have mass and take up space, gas is matter.

If students have trouble accepting or appreciating that a gas is made up of molecules, you could try helping them by giving them some numbers to think about. Although these numbers are huge and may be difficult to comprehend, at least students will get the idea that a gas is definitely made of something, takes up space, and has mass. Tell students that in an amount of air about the size of a standard beach ball, there are about 6×10^{23} gas molecules. This is about 600 billion trillion molecules.

Students may have difficulty imagining that gases have mass. It seems like balloons and beach balls, for example, get lighter when we inflate them. When you add air to a balloon or beach ball it actually gets a little heavier. The reason why it seems lighter is not because it has less mass, but because its volume increases so much when it is inflated. This big increase in volume with a small increase in mass makes the balloon or beach ball less dense. That is why it seems lighter when it is inflated. (We'll get to this when we study density in Chapter 3.)

2. Do a demonstration to show that gas has mass.

You will need a balance that measures in grams for either demonstration. If you don't have this type of balance, you can show videos of each demonstration.

www.middleschoolchemistry.com/multimedia/chapter1/lesson5#air_has_mass_ball
www.middleschoolchemistry.com/multimedia/chapter1/lesson5#air_has_mass_can



Materials for the demonstration

- Basketball, very deflated
- Balance that measures in grams
- Pump
- Can of compressed gas (available at any office supply store)

Procedure

A. Basketball

1. Place the deflated ball on the balance to get the initial mass.
2. Ask students if they think the ball will weigh more or less after you pump air into it.
3. Pump as much air into the basketball as you can and then put it back on the balance.



B. Can of compressed gas

4. Place a can of compressed gas on a scale and check its mass.
5. Ask students whether it will weigh more, less, or the same if you squeeze the trigger and let some gas out.
6. Shoot gas out of the can for a few seconds and then place the can back on the scale.



Expected results

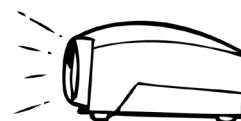
The basketball should weigh 2–4 grams more than when it was deflated. The can will weigh a few grams less than it did initially.

3. Show an animation of the molecules of a gas.

Show the molecular model animation *Particles of a Gas*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson5#particles_of_a_gas

Explain to students that the molecules of a gas have very little attraction for one another and barely interact with each other. They just collide and bounce off. It may be hard for students to accept, but in the space between the gas molecules there is nothing.



Note: An inquisitive student might ask: If gas molecules aren't attracted to each other and can just float around, why don't they all just float away? That is a very good question. In fact very light gases like hydrogen and helium have floated away and there are very little of these gases in our atmosphere. Different heavier gases, such as nitrogen, oxygen, water vapor, and carbon dioxide, surround the Earth. In the big picture, gravity holds these gases near the Earth as our atmosphere.

Give each student an activity sheet.

Students will answer questions about the demonstration on the activity sheet. The *Explain It with Atoms & Molecules* 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.



EXPLORE

4. Have students do an activity to find out how heating and cooling affect gases.



Question to investigate

How does heating and cooling affect a gas?

Materials for each group

- 2 clear plastic cups
- 8-oz plastic bottle
- Detergent solution in a cup
- Hot water (about 50 °C)
- Cold water

Teacher preparation

Make the detergent solution for the entire class by adding 4 teaspoons of dishwashing liquid and 4 teaspoons of sugar to $\frac{1}{2}$ cup of water. Gently stir until the detergent and sugar are dissolved. Place about 1 tablespoon of detergent solution in a wide clear plastic cup for each group.



Procedure

A. Warming the air inside the bottle

1. Pour hot water into an empty cup until it is about $\frac{1}{2}$ -full.
2. Turn the bottle over and dip the opening of the bottle into the detergent to get a film of detergent covering the rim.



3. While holding the bottle, slowly push the bottom of the bottle down into the hot water.

Ask students:

- **What can you do to make the bubble go down?**

If students have trouble thinking of an answer, remind them that heating the gas increased the speed of the molecules, which made the bubble grow. Students should suggest that they should cool the gas in the bottle. This can be done by putting the base of the bottle into cold water.

B. Cooling the air inside the bottle

4. Pour cold water into another cup until it is about $\frac{1}{2}$ -full.
5. If there is still a bubble on the bottle, slowly push the bottom of the bottle down into the cold water.
6. If a bubble is not still on the bottle, make another bubble by dipping the opening into detergent and then pushing the bottom of the bottle into hot water again.
7. While holding the bottle, slowly push the bottom of the bottle down into the cold water.



Expected results

When the bottle is placed in hot water, a bubble forms at the top of the bottle. When the bottle is placed in cold water, the bubble gets smaller. It may actually be pushed down into the bottle.

5. 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.

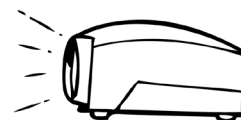


- **What happened to the film of detergent solution when you placed the bottle in hot water?**
It formed a bubble.
- **What happened to the bubble when you placed the bottle in cold water?**
It shrunk and went into the bottle.

Tell students that you will show them an animation to help explain what caused the bubble to grow and shrink when the air in the bottle was heated and cooled.

EXPLAIN

6. Show an animation of a bubble as it is heated and cooled.



Show the animation *Heating and Cooling Gas in a Bottle*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson5#heating_cooling_gas_in_bottle

Tell students that the red arrows in the animation represent the outside air pushing down on the bubble film. Explain that heating the air inside the bottle makes the molecules move faster. These faster-moving molecules hit the inside of the bottle and the bubble film harder and more frequently. These molecules push against the inside of the bubble film harder than the surrounding air pushes from the outside. This pushes the bubble film up and out, forming a bubble.

Cooling the gas makes the molecules move more slowly. These slower-moving molecules hit the inside of the bottle and the bubble film less often and with less force. The molecules in the surrounding air are moving faster and push against the bubble from the outside. Since these outside molecules are pushing harder, the bubble gets pushed down and gets smaller.

7. Have students answer the questions about the growing and shrinking bubble on the activity sheet.



Give students time to complete the following questions. They should refer to the drawing included on the next page and on the activity sheet.

Once they have answered the questions, discuss their explanations as a whole group.

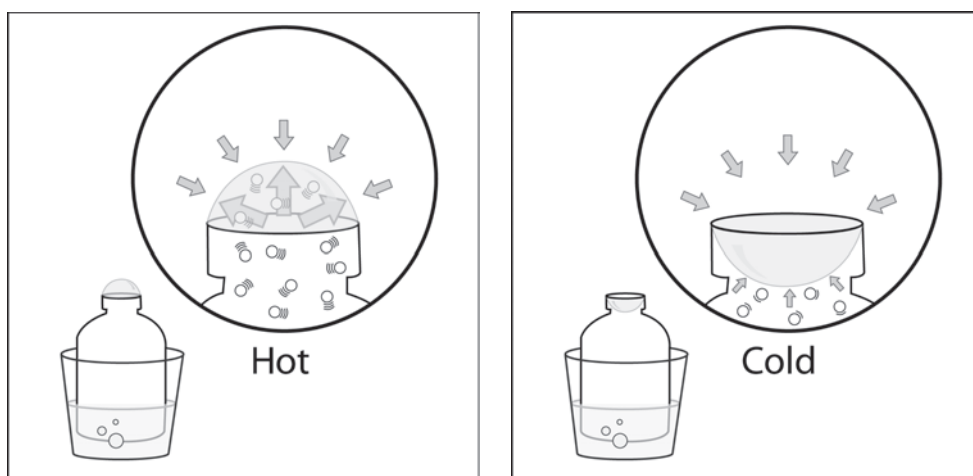
- **What caused the bubble to form when you placed the bottle in hot water? Be sure to write about the speed of the molecules inside the bottle and the pressure from the outside air.**

Point out that the molecules of air inside the bottle move faster when they are heated and push harder against the outside air. This makes the bubble form.

- **Why did the bubble get smaller when you placed the bottle in cold water? Be sure to write about the speed of the molecules inside the bottle and the pressure from the outside air.**

When the air inside the bottle is cooled, the molecules move slower and do not push as hard against the outside air. The outside air pushes against the bubble, making it go down.

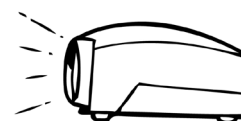
Read more about the contraction and expansion of gases in the additional teacher background section at the end of this lesson.



3. Have students compare the molecules in solids, liquids, and gases.

Show the molecular model animation *Comparing Solids, Liquids, and Gases*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson5#comparing_solids_liquids_and_gases



Be sure students realize that the molecules shown are from three different substances all at room-temperature. The solid is not melting to become a liquid and the liquid is not evaporating to become a gas. The model is not trying to show state changes but instead show three different substances (such as metal, water, and air), which are solid, liquid, and gas at room-temperature.

Explain the following differences to students:

- **Solid**—Particles (atoms or molecules) are very attracted to one another. They vibrate but do not move past one another. The atoms or molecules stay in fixed positions because of their strong attractions for one another. A solid has a definite volume and a definite shape.
- **Liquid**—Particles (atoms or molecules) are attracted to one another. They vibrate but are also able to move past one another. A liquid has a definite volume but does not have a definite shape.
- **Gas**—Particles (atoms or molecules) are not attracted to each other much at all and move freely. A gas does not have a definite shape or volume. The atoms or molecules of a gas will spread out evenly to fill any container.

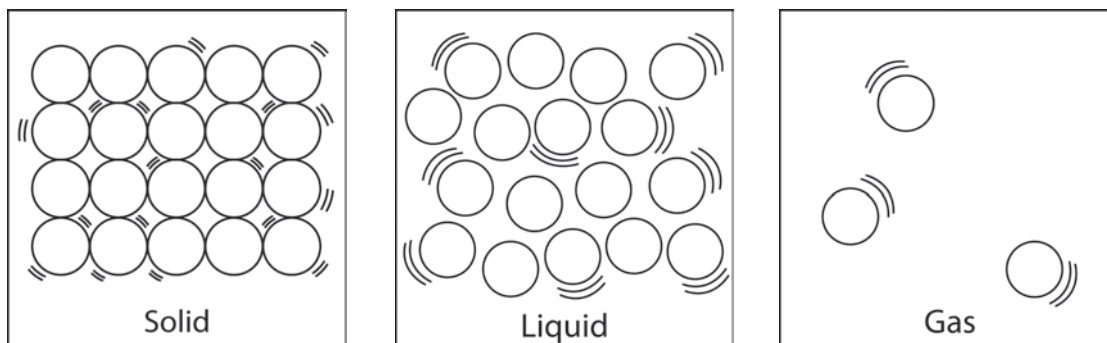
You could use the following example to help students appreciate how far apart the molecules of a gas are compared to the molecules in a liquid or solid:

- The molecules that make up a gas are about 100 to 1000 times further apart than the molecules of a solid or liquid. Imagine what a tablespoon of water looks like. If that same number of molecules was a gas, they would be spread out enough to fill up a whole beach ball. At room-temperature they are moving at about 1000 miles per hour, but over very short distances.

Draw or project the illustration *Solid, Liquid, and Gas*.

www.middleschoolchemistry.com/multimedia/chapter1/lesson5#solid_liquid_and_gas

Have students use the projected illustration as a reference as they draw a model of solids, liquids, and gases on their activity sheet. Point out that the number of motion lines is the same for the solid, the liquid, and the gas. This indicates that the different substances are at the same temperature. Have students write captions like those listed below to describe the molecules in solids, liquids, and gases.



- | | | |
|---|---|--|
| <ul style="list-style-type: none">• Attractions strong enough to keep atoms in orderly arrangement• Vibrate in fixed positions• Definite volume and shape | <ul style="list-style-type: none">• Attractions keep particles together but they can slide past each other• Random arrangement• Definite volume, not definite shape | <ul style="list-style-type: none">• Attractions too weak to keep particles together• Particles move independently• No definite volume or shape |
|---|---|--|

EXTEND

4. Have students apply what they have learned to explain why a balloon grows when it is heated.

Tell students to consider the following scenario:

Imagine that you work at a party store during the summer. You are going to ride home with the owner of the store whose car has been sitting in the hot sun all day long. The owner tells you that you can take home a big bunch of balloons, but advises you to not blow the balloons up all of the way. Knowing what you do about heating the molecules of a gas, explain why the owner's advice is wise.

You may choose to show the animation *Heating Molecules of a Gas* if you would like to give students a hint.

www.middleschoolchemistry.com/chapter1/lesson5/#heating_and_cooling_gas

DEMONSTRATION—BASKETBALL AND COMPRESSED GAS

The demonstrations with the basketball and the can of compressed air were meant to show something about gases and matter. Matter is anything that has mass and takes up space.

1. Think about the demonstration with the deflated and inflated basketball. The basketball weighed more after it was inflated with air than when it was deflated. How does this show that gas is matter?



2. Think about the demonstration with the can of compressed gas. The can weighed less after some gas was shot out of the can. How does this show that gas is matter?



EXPLAIN IT WITH ATOMS & MOLECULES

You saw an animation of gas molecules inside a balloon.

3. What did you notice about the molecules of a gas:
 - Do the molecules of a gas have strong or weak attractions?
 - Are the molecules of a gas randomly or orderly arranged?
 - When the molecules of a gas hit each other, do they normally stick together or bounce off?

ACTIVITY

Question to investigate

How do heating and cooling affect a gas?



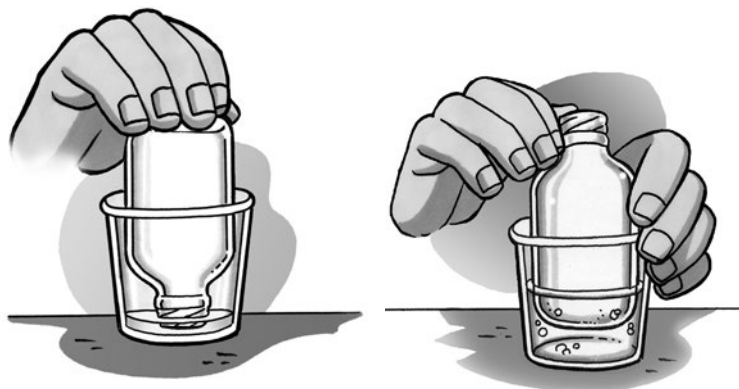
Materials for each group

- 2 clear plastic cups
- 8-oz plastic bottle
- Detergent solution in cup
- Hot water
- Cold water

Procedure

A. *Warming the air inside the bottle*

1. Pour hot water into an empty cup until it is about $\frac{1}{2}$ -full.
2. Turn the bottle over and dip the opening of the bottle into the detergent to get a film of detergent covering the rim.
3. While holding the bottle, slowly push the bottom of the bottle down into the hot water.



B. *Cooling the air inside the bottle*

4. Pour cold water into another cup until it is about $\frac{1}{2}$ -full.
5. If there is still a bubble on the bottle, slowly push the bottom of the bottle down into the cold water.
6. If a bubble is not still on the bottle, make another bubble by dipping the opening into detergent and then pushing the bottom of the bottle into hot water again.
7. While holding the bottle, slowly push the bottom of the bottle down into the cold water.

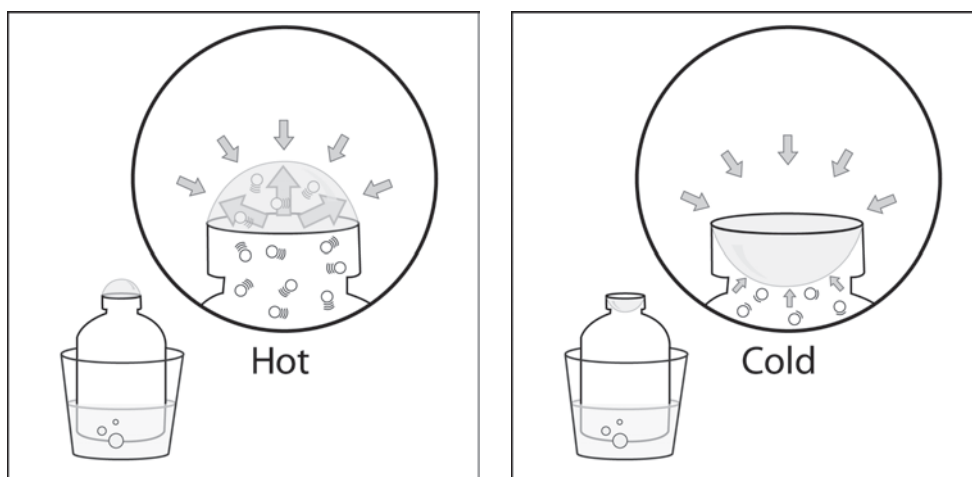


WHAT DID YOU OBSERVE?

4. What happened to the film of detergent solution when you placed the bottle in hot water?
5. What happened to the bubble when you placed the bottle in cold water?

EXPLAIN IT WITH ATOMS & MOLECULES

You saw an animation showing the air molecules inside a bottle when it is placed in hot and cold water. Think of the animation and use the drawing below as a reference to answer the questions at the top of the next page.



6. What caused the bubble to form when you placed the bottle in hot water? Be sure to write about the speed of the molecules inside the bubble and the force on the bubble from the outside air.

7. Why did the bubble get smaller when you placed the bottle in cold water? Be sure to write about the speed of the molecules inside the bubble and the force on the bubble from the outside air.

You saw an animation about the molecules in solids, liquids, and gases.

8. Draw circles to represent the molecules in a solid, liquid, and gas. Because all three different substances are all at the same temperature, draw the same number of motion lines near the circles for each substance. Under each box, write about the arrangement and motion of the molecules and the attractions the molecules have for one another.

Solid	Liquid	Gas

TAKE IT FURTHER

9. Imagine that you work at a party store during the summer. You are going to ride home with the owner of the store whose car has been sitting in the hot sun all day long. The owner tells you that you can take home a big bunch of balloons, but advises you to not blow the balloons up all of the way. Explain why the owner's advice is wise. Be sure to discuss how heating affects the motion of the molecules in a gas.

Chapter 1—Student Reading

Chemistry is the study of matter

You could say that chemistry is the science that studies all the stuff in the entire world. A more scientific term for “stuff” is “**matter**.” So chemistry is the study of matter. Matter is all the physical things in the universe. All the stars in the galaxies, the sun and planets in our solar system, the Earth, and everything on it and in it are matter.



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All human-made objects, all organisms, the gases in the atmosphere, and anything else that has mass and takes up space, including you, are examples of matter.

Chemistry is special because it looks at matter all the way down to its smallest parts: the **atoms** and **molecules** that matter is made of. To give you an idea about how small atoms and molecules are, use a metric ruler to look at the length of one millimeter. It is about the size of a dash like this one -. Try drawing a tiny line or dot that is about $1/10$ as long as the dash. It might be about the size of a period like the one at the end of this sentence. A hydrogen atom is about 1 ten millionth of the size of the period. So it would take about 10 million hydrogen atoms lined up next to each other to go from one side of the period to the other.

Here is another way to imagine how small atoms and molecules are. In about 1 tablespoon of water, there are about 600 billion trillion water molecules. That's 600,000,000,000,000,000,000,000. This number is so huge that even if you could count one million molecules every second, it would take you about 200 million centuries or about 20 billion years to count all the molecules in a tablespoon of water.

Studying chemistry can help make sense of many of the different things you see and do every day. What you eat and drink, the weather outside, the soap and water you wash with, and the clothes you wear, are all a result of chemistry. The sports equipment you use, the materials your house is made of, the way you get to school, and the electronic equipment you use are all a result of the interactions of atoms and molecules.



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Having a better idea of what atoms and molecules are and how they interact can help you better understand the world around you.

Matter is made of atoms and molecules

We have already used the term *atom* and *molecule* a couple of times. You will learn a lot more about atoms and molecules in later chapters. For now, let's say that atoms and molecules are the extremely tiny particles that make up all the matter on Earth. An atom is the basic building block of all matter. A molecule is made of two or more atoms connected or bonded together.

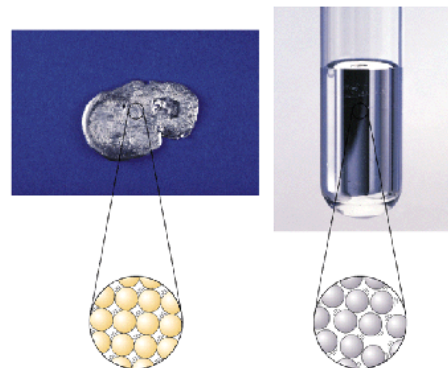
Even though atoms and molecules are not the same, the model we are using in Chapter 1 shows both atoms and molecules as little circles or spheres. This model makes it easier to show some of the basic characteristics of the different states of matter on Earth.



Matter—Solid, Liquid, Gas

On Earth, matter is either found as a **solid**, **liquid**, or **gas**. A particular solid, liquid, or gas might be made up of individual atoms or molecules.

Here is a simplified model of three different substances. One is a solid, another is a liquid and the other is a gas



In the picture, the little motion lines show that the particles (atoms or molecules) that make up the solid, liquid, and gas are moving. In later chapters, the models of atoms and molecules will be shown with more detail.

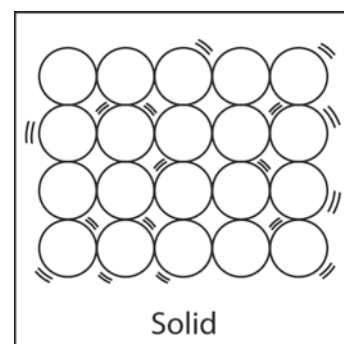
As you look at these pictures, think about these two big ideas which are always true when talking about matter:

- Matter (solid, liquid, and gas) is made up of tiny particles called atoms and molecules.
- The atoms or molecules that make up matter are always in motion.
- These first two ideas make up a very important theory called the Kinetic-molecular theory of matter.

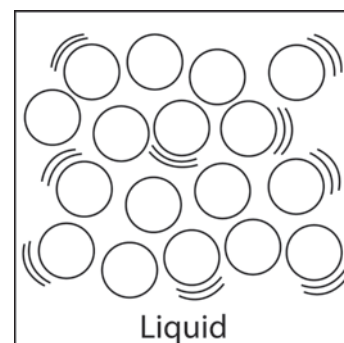
Another big idea is that:

The **atoms** or molecules that make up a solid, liquid or gas are attracted to one another.

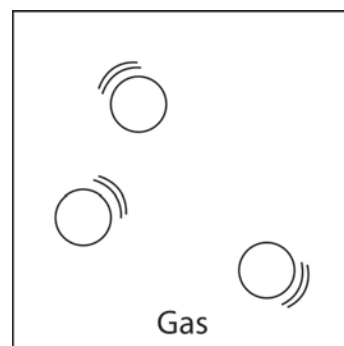
In a **solid**, the atoms are very attracted to one another. Because of this strong attraction, the atoms are held tightly together. The attractions are strong enough that the atoms can only vibrate where they are. They cannot move past one another. This is why a solid keeps its shape.



In a **liquid**, the molecules are also in motion. The attractions between the molecules in liquids are strong enough to keep the molecules close to each other but not in fixed positions. Although the molecules stay very near one another, the attractions allow the molecules of a liquid to move past one another. This is why a liquid can easily change its shape.



In a **gas**, the molecules are also moving. The attractions between the molecules of a gas are too weak to bring the molecules together. This is why gas molecules barely interact with one another and are very far apart compared to the molecules of liquids and solids. A gas will spread out evenly to fill any container.

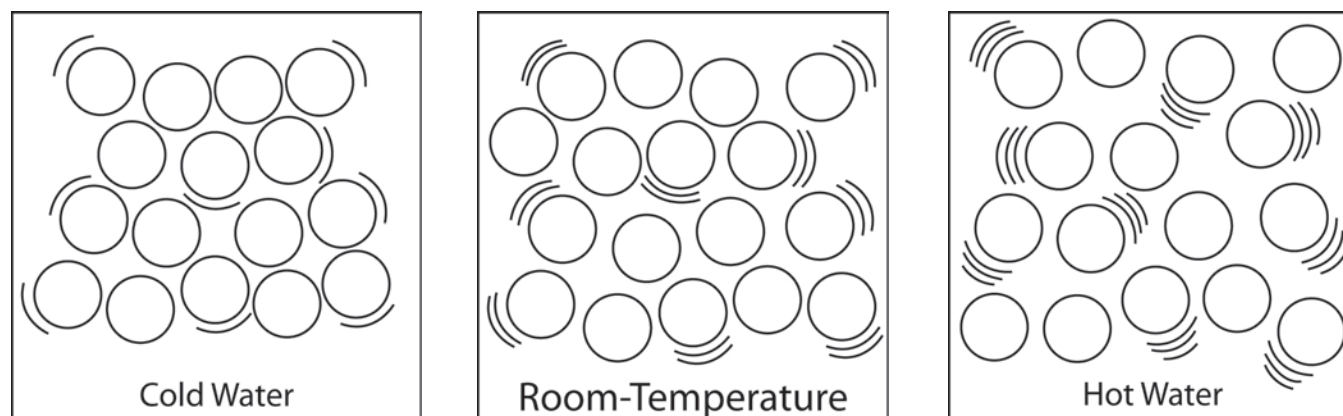


When looking at the different states of matter, it's kind of like a competition between the attractions the molecules have for each other compared to the motion of their molecules. The attractions tend to keep the atoms or molecules together while the motion tends to make the atoms or molecules come apart.

Comparing Matter			
	Solids	Liquids	Gases
Attractions	Atoms or molecules are very attracted to one another.	Atoms or molecules are attracted to one another.	Atoms or molecules are barely attracted to one another.
Movement	Vibrate but do not move past one another.	Vibrate but are able to move past one another.	Vibrate and move freely past each other.
Volume and Shape	Have a definite volume and a definite shape.	Have a definite volume, but does not have a definite shape.	Does not have a definite volume or a definite shape.

Heating and cooling liquids

Heating and cooling a liquid can affect how far apart or close together the molecules are.



One example is the red alcohol inside the thin tube of a thermometer. When the thermometer is heated, the molecules of alcohol move faster. This faster motion competes with the attraction between the molecules which causes them to spread out a little. They have nowhere else to go so they move up the tube.

When the thermometer is cooled, the molecules of alcohol slow down and the attractions bring the molecules closer together. This attraction between the molecules brings the alcohol down in the tube.

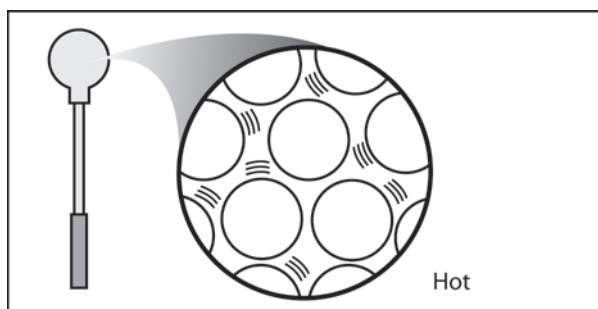
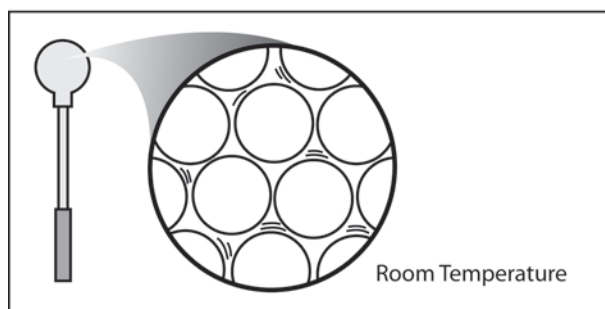
Heating and cooling solids

There is a device made out of a metal ball and ring that lets you see the effect of heating and cooling a solid. At room temperature, the ball just barely fits through the ring.

When the ball is heated sufficiently, it will not fit through the ring.

This is because heating the metal ball increases the motion of its atoms. This motion competes with the attractions between the atoms and makes the atoms move slightly further apart. The slightly larger ball no longer fits through the ring.

When the metal ball is cooled, the atoms slow down and their attractions bring the atoms closer together. This allows the metal ball to fit through the ring again.

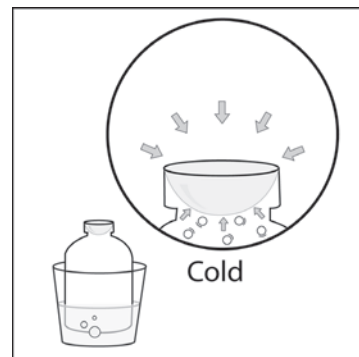
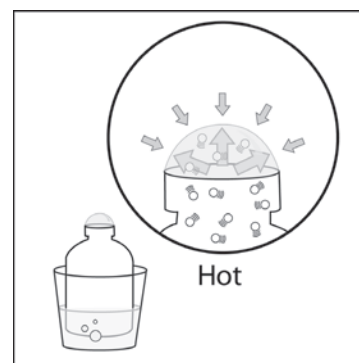


Heating and cooling gases

The molecules of a gas are not very attracted to each other and are much further apart than in liquids and solids. This is why heating a gas easily increases the motion of the gas.

For example, if you dip the opening of a bottle in a detergent solution and then heat the bottle, a bubble will form on the bottle. This happens because heating the bottle increases the motion of the gas molecules inside the bottle. Since molecules of the gas are not very attracted to each other, they spread out quickly and easily. The molecules hit the inside of the bottle and the bubble film harder and more often. The molecules push against the inside of the film harder than the surrounding air pushes from the outside. This pushes the bubble film out and forms a bubble.

If you cool the bottle while the bubble is still on top, the bubble will shrink and may go inside the bottle. This happens because cooling the gas causes its molecules to slow down. These slower-moving molecules hit the inside of the bubble film less often and with less force. The molecules in the outside air are moving faster and push against the bubble from the outside. Since the outside molecules are pushing harder, the bubble gets pushed down and in and gets smaller.



Additional Teacher Background

Chapter 1, Lesson 5, p.49

Contracting and expanding happens differently for a gas than it does for liquids and solids.

Cooling a liquid or solid

When a liquid or solid is cooled, the particles (atoms or molecules) slow down. The slower motion allows the attractions between the particles to pull themselves closer together causing the liquid or solid to contract.

Cooling a gas

But it works differently for gases. When a gas in a flexible container like a balloon or bubble is cooled, its atoms or molecules also slow down. But the attractions between the particles of a gas are so weak that they cannot pull themselves closer together like in a liquid or solid. Instead, the slower-moving molecules hit the inside of the balloon or bubble less frequently and with less force. This results in a lower pressure inside the bubble than outside. The higher pressure on the outside pushes on the bubble, making it contract.

Heating a liquid or solid

When a liquid or solid is heated, the particles it is made of move faster. This increased motion competes with the attractions the particles have for each other causing them to move slightly further apart.

Heating a gas

When a gas is heated, the particles also move faster but they do not have to compete with significant attractions. The particles hit the inside of the bubble more frequently and with more force. This results in a higher pressure inside the bubble than outside. The higher pressure on the inside pushes on the bubble, making it expand.